THE LICHEN COMMUNITIES OF THE SOUTHEASTERN MISSOURI OZARKS: LESSONS IN SPECIES ASSOCIATIONS, HABITAT PARTITIONING, AND DISTRIBUTION FROM THE MOFEP STUDY

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Jeri Peck, University of Missouri*
Jennifer Grabner, Missouri Department of Conservation
Doug Ladd, The Nature Conservancy

Abstract:

The lichen communities of the nine MOFEP sites in the Missouri Ozarks were characterized from sampling of the ground layer, tree-bases, midboles, and canopy branches. Of the 181 species observed, the majority were crustose (55%) or foliose (32%) lichens, with a mere 6%, all relatively rare, have nitrogen-fixing capabilities. Two assemblages of dominant species in each of the four habitats were recognized on the basis of frequency and cluster analyses. These "typical" and "common" species demonstrated a pattern of co-occurrence independent of physiognomy (crustose, foliose, fruticose, and gelatinous) and contributed so strongly to analyses of the full lichen community that they could be used as a surrogate for the full community in future studies concerned primarily with the dominant members of the lichen community. Only a quarter (26%) of all species occurred across all four habitats, with the majority of dominant species demonstrating distinct habitat, host, or substrate preference. For instance, *Lecanora strobilina* was dominant in ground samples (albeit as a result of litterfall), *Cladonia* squamules on tree-bases, *Physcia americana* and *Punctelia rudecta* on midboles, and *Lecanora strobilina* on canopy branches. Relative species composition and abundance was strongly associated with the presence of the red oak group vs. the white oak group in the overstory and suggestively with aspect class, geology, bedrock, landform, and soil type (but not with ecological classification type). Lichen diversity measures varied substantially among habitats and substrates and were weakly associated with the presence of white or red oak in the overstory. Recommendations for future lichen sampling methods in MOFEP and additional hypotheses are presented.

Introduction

The Missouri Ozark Forest Ecosystem Project (MOFEP; Shifley & Brookshire 2000) has provided the framework for a wide range of projects, from those that specifically address the impacts of prescribed forest management alternatives to those that gather fundamental baseline data about poorly known ecological groups. Throughout the history of resource management, organisms that at one time were in the latter category have become those that require active, *pro*active resource management. Occasionally baseline data for these groups has been available, but most often

* Current address: jeripeck@hotmail.com

managers have instigated belated baseline studies and been forced to base resource use decisions on insufficient data during the lag until research findings were available.

Lichens fall into the category of poorly known ecological groups in Missouri (Ladd 1991a). Progress has been made in recent decades to characterize the state lichen flora, but systemic conservation (as opposed to species-targeted conservation) requires a broader understanding of lichen ecology (Ladd 1993). Although some ecological functions have been documented in this and other regions [e.g., material for birds' nests and nutrient cycling sinks (Ladd 1998), food for birds (Pettersson et al. 1995) and wildlife (Sharnoff 1994, Stevenson 1978)], the relative importance of lichens in these functions, as well as other possible functions, have remained completely unknown. Throughout the country, lichens are gaining attention as useful indicators of air quality (de Wit 1983, McCune et al. 1997b, Showman 1975), for use in vegetation classifications or indicators of other groups of rare organisms (e.g., Nilsson et al. 1994), as important contributors to nutrient cycling (e.g., Knops et al. 1996, Pike 1978), and as rare species that require protection (e.g., Ladd 1991a). With the exception of Ladd (1996), sufficient data to evaluate the potential contributions of lichen communities in the Ozarks have hitherto been lacking.

Because any or all of these functions may be relevant in the Ozarks region of Missouri, lichen community sampling was incorporated into MOFEP in 1996. The long-term experiment will ultimately examine the impacts of standard forest management practices on a wide array of organisms and ecosystem attributes. That there are differences in lichen communities between old-growth and managed stands is understood (e.g., Lesica et al. 1991, Neitlich 1993), in some cases with ecological implications for entire food webs (Pettersson 1997). Given the potential for edge effects on lichens to extend more than 45 m into a forest (Glenn et al. 1997) and for lichen dispersal from retained trees (Dettki et al. 2000) and neighboring stands (Esseen & Renhorn 1998) to decline precipitously with distance, differences in partial-cutting methods may be particularly important. As proposals for practices such as retaining mature trees have been put forth to preserve lichen diversity while enabling timber harvest in the Pacific Northwest (Rosentreter et al. 1995) and other regions, the realization has grown that such practices must be scientifically tested. A study in the lodgepole pine ecosystems of British Columbia indicated that diversity and abundance of lichens was lower 2.5 years after harvest, with a significant negative association of lichen diversity with the amount of timber harvested, although no differences among partial-cutting treatments were observed (Miege et al. 2001). Prominent lichenologists have led the call for research more closely related to these management activities (McCune et al. 2000). Recently, a retrospective analysis of lichen communities of conifer-dominated forests in the Pacific Northwest found thinning to have "little effect" (Peterson & McCune 2001). We follow-up here on the foresight that provided this dataset (*cf.* Ladd & Grabner 1996) and report on a thorough analysis of these data to elucidate the patterns necessary to guide future lichen studies on MOFEP and other Ozark woodlands, and to help guide resource management decisions.

Lacking sufficient data for the Missouri Ozarks ecosystem, sampling stratification in the current study was based primarily on results from other parts of the country. Lichen communities found in the canopy generally differ from those found on tree-bases or boles (e.g., Hale 1965, Hoffman & Kazmierski 1969, McCune et al. 2000, Pike et al. 1972). In particular, lichen communities have been seen to vary along a gradient from tree-bases to midboles to the canopy (Ladd 1996, Lang et al. 1980, McCune 1993, McCune et al. 1997), presumably due to gradients in

photosynthetic activity and humidity (Hosokawa et al. 1964, Szczawinski 1953). Variability has also been recorded among host tree species (Jesberger & Sheard 1973, McCune & Antos 1982, Schmitt & Slack 1990), branch size in the canopy (*cf.* Esseen et al. 1996, Hilmo 1994), decay class in downed woody debris (*cf.* Søderstrom 1988), and substrate in ground lichen flora (Pharo & Vitt 2000).

Our objectives were to:

1. Determine if there are discrete, consistently repeating lichen assemblages among the 9 MOFEP sites and identify the members of these assemblages. Evaluate the association of lichen physiognomy (crustose vs. foliose vs. fruticose vs. gelatinous) and nitrogen-fixing capability with these assemblages.
2. Quantify the association of the relative species composition and abundance and diversity of these assemblages with the available environmental characteristics.
3. Determine if these lichen assemblages vary consistently with respect to classifications that can be used to stratify future sampling toward the goal of evaluating the impacts of the silvicultural treatments on MOFEP on lichen communities.
    - Contrast among *a priori* habitat groups [canopy branches vs. tree midboles vs. tree bases vs. ground-soil vs. ground-rock vs. ground-wood].
    - Contrast among three size classes (twig vs. branch vs. log) and two decay classes of ground-wood
    - Contrast canopy branch samples among four size classes
    - Contrast lichen diversity among *a priori* treatments, habitats, and ecological classifications.
4. Consider the interpretation of these results with respect to issues of habitat partitioning, host specificity, and distribution.
5. Evaluate the sampling adequacy of the 1996 sampling and make recommendations on sampling sizes and procedures for future remeasurements.
6. Develop hypotheses based on these results, which can be tested on the neighboring Chilton Creek lichen community dataset and/or in future studies.

Method

Sites

The nine 700+ acre sites are contiguous forested tracks, largely free of manipulation for at least the 45 years prior to the initiation of the MOFEP experiment, located in the southeast Missouri Ozarks (Shifley & Brookshire 2000). Most overstory trees in these second growth mixed hardwood stands (primarily white oak-*Quercus alba*, black oak-*Quercus velutina*, and scarlet oak-*Quercus coccinea* with scattered other hardwoods and shortleaf pine-*Pinus echinata*) ranged from 50 to 70 years old at the time of sampling. The lichen sampling reported here occurred prior to the application of the overstory treatments, which are described in detail in Sheriff (2002).

Lichen community data were collected for trees and the ground layer in six plots at each site from March-May 1996 using the standard MOFEP vegetation plot design (Jensen 1993). Plots were selected to ensure homogeneity of parent material, aspect, and major vegetation groups and all

were on shoulder or backslope positions (10-60% slope; Ladd & Grabner 1996). Tree sampling was conducted in the northern 0.42 ha subplot of each 0.20 ha circular vegetation plot and included all trees greater than 11.43 cm (4.5") in diameter at breast height. The bases and midboles (at breast height) of each tree were sampled using a 0.25 m^2 variable length cylindrical quadrat. Ground sampling was conducted along four 24.8 m permanent line transects dissecting the entire 0.2 ha vegetation plot. Along each transect, five 0.25 m^2 quadrats were placed at a random point within five meter intervals and centered on the transect line. Canopy sampling was facilitated by the harvest of trees for the greater MOFEP experiment in October 1996 and was conducted in three randomly selected plots at each site that were measured for tree and ground sampling. Two dominant or co-dominant trees were sampled in each plot, each providing two separate branches, typically from opposite sides of the tree. Four 30.48 cm (12") samples were cut from each branch, representing 4 size classes on the basis of diameter of the largest end (1.27 cm=0.5", 3.81 cm=1.5", 7.62 cm=3", and 10.16 cm=4").

In all cases, within the quadrat all lichen species were recorded (nomenclature follows Ladd 2002) and a cover value assigned. Cover values were as follows: 1 = <1% cover; 2 = 1-5% cover or well-represented throughout quadrat; 3 = 6-25% cover or essentially ubiquitous; 4 = >25% cover or >5% cover and well distributed; 5 = >50% cover and nearly uniformly dominant throughout the quadrat. Data analyzed here are cover class midpoints (0.5%, 3%, 15%, 32.5%, 75%), averaged to the site level where appropriate.

For ground samples, note was also taken of the substrate upon which the lichen was found, including: soil, rock (rock type), and downed woody debris (twigs= diameter < 0.5", branches = diameter >0.5", logs = diameter > 2", or lignum = loose fragments). Downed woody debris with diameters greater than 2" were also assigned a MOFEP decay class [1-5, least to most decayed; Appendix A in Shifley & Brookshire (2000)].

Environmental variables included in the analyses were tree species, tree densities and basal areas, slope, aspect, and ELT-P (ecological landtype, Meinert et al. 1997). Categorical variables recorded included block, site, plot, silvicultural treatment (control, even aged harvest, uneven aged harvest), soil type, bedrock type, aspect class (1=exposed, 2=neutral, 3=protected), geology, and landform.

Analyses

Lichen Assemblages

To identify the dominant, consistently repeating lichen assemblages present on these sites, three approaches were taken. First, the frequency of all species across subplots and sites was calculated (i.e., the ratio of the number of subplots or sites in which a species occurred out of the total number of subplots or sites, expressed as a percent).

Second, groups of similarly distributed species were identified at the site level using cluster analysis on a transposed matrix of species x 9 sites, after deleting species that occurred in only one site (Figure 1). Third, groups of similarly distributed species were identified at the subplot level using cluster analysis on a transposed matrix of species x subplots and the consistency of these groups across all nine sites was evaluated, after deleting species that occurred in only one subplot.

For these analyses, cluster analysis in PC-ORD v. 4.01 (McCune & Mefford 1999) was used. This is a hierarchical, agglomerative, polythetic grouping algorithm (see Gauch 1982) using, in this case, the Sørensen coefficient (also known as the Bray & Curtis or Czekanowski coefficient) as a distance measure (Sørensen 1948).

Based upon these analyses, two general lichen assemblages were identified. The first consists of species "typical" to the four sampled habitats (ground, tree bases, tree boles, and canopy branches) at these sites. These species had a frequency of 100% at the site level and more than 10% at the subplot level, clustered together at the site level and clustered together more than 50% of the time at the subplot level. The second assemblage consists of species "common" to these habitats at these sites. These species had a frequency of more than 50% at the site level and more than 10% at the subplot level and clustered together at the site level, although not always more than 50% at the subplot level. These assemblages are, by definition, not necessarily composed of taxonomically or ecologically related species, but rather those demonstrating strong patterns of co-occurrence.

The association of lichen physiognomy with these assemblages was determined by overlaying, at the site level, the physiognomy of a species onto the cluster of the transposed matrix and looking for overlap with the assemblage clusters. The morphological classes were: crustose, foliose, fruticose, and gelatinous (see Ladd 2002 for definitions). The association between the morphological classifications and membership in the identified assemblages was also tested using multi-response permutation procedures (MRPP in PC-ORD v. 4.01, McCune & Mefford 1999), which contrasts the within-group variation in the species space distance matrix among *a priori* groups (i.e., species were coded as to their group membership (physiognomy) and these groups were then contrasted on the basis of their homogeneity; see Mielke et al. 1981). The same approach was taken to evaluate associations with the nitrogen-fixing capability of lichen species. Group membership for physiognomy and nitrogen fixation are shown in Appendix 1.

Habitat and Substrate Relations

Variation in the lichen community among habitats and/or substrates was evaluated on the basis of all lichen taxa found in this sampling. Contrasts of relative species composition and abundance were made at the site level using MRPP analysis after species occurring in fewer than 2 plots were deleted and data were relativized to species totals (i.e., by the sum of mean cover class midpoints for a given species across all sites) and arcsine-squareroot transformed, which has been shown to improve the statistical properties of proportion data (Sokal & Rohlf 1981).

Significant differences were evaluated with a calculation of indicator values (IV; Dufrene & Legendre 1997, McCune & Mefford 1999). Indicator values are the product of the relative frequency and abundance of a species across the groups of interest, and provide a simple and objective way of gauging the tendency for a species to occur in a particular set of samples. As a relative measure, no standard cutoff IV was used to determine substrate or habitat preference. Rather, significant IVs (based on a p=0.05 cutoff from a Monte Carlo procedure) were contrasted among the groups of interest and differences greater than 30 were taken to indicate a greater frequency and abundance of a given species in a given habitat. Similar contrasts were made among the sizes of canopy branches, sizes and decay classes of down woody debris, and several categories of ground substrate. We looked at several different partitions of ground substrates,

including two classes (litterfall or non-litterfall), six classes (soil, stone, lignum, fresh log/branch/twig, decayed log/branch/twig, and fresh twig/free-form), and ten classes (soil, sandstone, chert, stone, lignum, logs, branches, twigs, pinecones, and free-form).

Specimens collected on the ground habitat were recorded for substrate type. The association of substrate with the species assemblages was also determined by overlaying, at the site level, the proportion of species found on a given substrate onto a polar ordination diagram (Bray-Curtis ordination in PC-ORD v. 4.01, McCune & Mefford 1999). Polar-ordination has been shown to perform well with multivariate ecological data (Beals 1984), produced, in this case, virtually identical results to nonmetric multidimensional scaling (NMS in PC-ORD), and hence was used as it required less computation time.

Environmental Relations

The association between the lichen community and the measured environmental variables were analyzed at the site level for a) all of the samples lichen species after species occurring in fewer than 2 plots were deleted and data were relativized to species totals and arc-sin-squareroot transformed, and for b) only typical and common species after similar transformations. Overlays of the environmental matrix onto the polar ordination diagrams were visually examined. When strong, consistent patterns were observed, correlations with the ordination axes were calculated for both environmental variables and lichen species. Only associations with $r > 0.45$ are reported.

Each site was analyzed separately to evaluate the association between the observed lichen assemblages and the measured environmental characteristics at the subplot level, including host tree species, using the same procedures as for the site level analysis above. Data were also analyzed for both all sampled species and only typical and common assemblages, but no transformations were deemed necessary. In addition, MRPP's were calculated for all categorical variables.

Because of the low percentage of variance explained by all ordinations, regression analysis of ordination scores on environmental characteristics was not deemed appropriate. In other words, due to high variability and small sample sizes, the attempt at reduction through ordination did not produce results reliable enough for predictive analysis, which may in any case not have been appropriate given the limited inferential power of this dataset.

Diversity

Four diversity measures were calculated at both the site and subplot level (using PC-ORD v. 4.01, McCune & Mefford 1999). Across a given unit of measurement (e.g., subplots within a site), these included: 1) gamma (γ) diversity, the total number of species (Whittaker 1972); 2) mean alpha (α) diversity, the average number of species (Whittaker 1972); 3) the mean Shannon-Weaver (H') measure of diversity, the log of the number of species of equal abundance (Shannon & Weaver 1949); and 4) the inverse of the Simpson's Index (D'), which calculates the likelihood that two randomly chosen individuals will be different species (Simpson 1949). These diversity measures were regressed (PROC GLM, SAS 6.12 1996) on the available environmental characteristics at the site and subplot levels. At the site level, these were the quantitative measures of basal area and density of individual oak species, as well as composite values for "white oak" vs.

"red oak" groups. At these sites, white oak species included white oak (*Quercus alba*) and post oak (*Q. stellata*) while red oak species included scarlet oak (*Q. coccinea*), black-jack oak (*Q. marilandica*), Northern red oak (*Q. rubra*), Shumard oak (*Q. shumardii*), and black oak (*Q. velutina*). At the subplot level, these were the categorical variables of ELT-P, geology, aspect, bedrock, landform and soil plus the quantitative measure of slope. Lichen diversity was also contrasted among various site-level groupings, including across sites, blocks, treatments, habitats, and substrate types, using analysis of variance (PROC GLM, SAS 6.12 1996) with Tukey's Studentized Range Test for multiple comparisons. In order to contrast canopy branch segments to one another, surface areas for each branch were estimated by assuming that the smallest size class was equivalent to a circular cone and the larger classes were equivalent to truncated cones

circular cone	truncated cone = parallelogram	
$SA = \pi r\sqrt{r^2 + h^2}$	$SA = \frac{h}{2(a + b)}$	Equation 1, 2

where "r" is the radius of the circle at the base, "h" is the height of the cone or parallelogram, and "a" and "b" are the lengths of the sides of the parallelogram. Species richness was then standardized by surface area before the analysis was conducted. Note that, in making these cross-habitat comparisons, we violate assumptions of independence and equal sampling probability.

Results

The Lichen Community

A total of 181 taxa were sampled across the four habitat types on these nine sites (Appendix 1). Forty-eight taxa (26%) occurred in all four habitat types and 80 (44%) in at least two, while 61 (34%) were found in only one. There were 100 (55%) crustose, 59 (32%) foliose, 15 (8%) fruticose, and 7(4%) gelatinous lichen taxa. Ten (5%) species were found to have nitrogen-fixation capabilities. Although none of the observed taxa are rare, threatened, or endangered in the state of Missouri, one species, *Tuckermannopsis cilaris*, has been placed on a "watch list" to reflect the restricted distribution of this species in the state (Ladd 1991a). Typically found in old growth *Pinus echinata* stands, the single occurrence of this species in this study was at the base of an *P. echinata* in Site 6.

A total of 107 taxa were collected from **ground** sampling (Appendix 1). Of these, 25 taxa (23%) occurred on all nine MOFEP sites, while 48 (45%) occurred in two-thirds of the sites. *Lecanora strobilina* actually occurred in over 75% of subplots (presumably as the result of litterfall), but 91 taxa (85%) occurred in fewer than 10% of subplots. The ground sampling was composed of 57 (53%) crustose, 41 (38%) foliose, 7 (7%) fruticose, and 2 (2%) gelatinous lichens. *Punctelia rudecta*, *Lecanora hybocarpa*, and *Usnea strigosa* were also commonly found in ground sampling.

A total of 122 taxa were collected from **tree-base** sampling. Of these, 20 (16%) were found in all MOFEP sites, while 38 (31%) occurred in two-thirds of the sites. *Cladonia* was the most common lichen on tree-bases at the subplot level, occurring in over 50% of subplots, but 102 (84%) species occurred in fewer than 10% of subplots. The tree-base sampling was composed of 63 (52%)

crustose, 41 (34%) foliose, 12 (10%) fruticose, and 6 (5%) gelatinous lichens. *Myelochroa aurulenta, Punctelia rudecta,* and *Physcia americana* were also commonly found in tree-base sampling.

A total of 118 taxa were collected from **midbole** sampling. Of these, 33 (28%) were found in all MOFEP sites, while 54 (46%) occurred in two-thirds of the sites. *Physcia americana* and *Punctelia rudecta* were the most prevalent species at the subplot level, occurring in over 50% of subplots, but 88 (75%) taxa occurred in fewer than 10% of subplots. The midbole sampling was composed of 70 (59%) crustose, 37 (31%) foliose, 6 (5%) fruticose, and 5 (4%) gelatinous lichens. *Physcia americana*, *Punctelia rudecta*, and *Candelaria concolor* were also commonly found in tree-base sampling.

A total of 84 taxa were collected from **canopy** sampling. Of these, 23 taxa (27%) were found on all 6 sampled MOFEP sites, while 35 (42%) occurred in two-thirds of the sites. *Lecanora strobilina* occurred in over 80% of subplots, but 58 (70%) taxa occurred in fewer than 10% of subplots. The canopy sampling was composed of 48 (57%) crustose, 34 (40%) foliose, and 2 (2%) fruticose lichens. *Usnea strigosa*, *Lecanora hybocarpa*, and *Buellia stillingiana* were also commonly found in tree-base sampling.

Lichen Assemblages

The first identified assemblage consisted of 27 species that were "typical" for these habitats on these sites (Appendix 1). There were 12 typical species on the ground, 12 on tree-bases, 7 on midboles, and 11 in the canopy. The second assemblage consisted of 24 species that were "common" for these habitats on these sites. There were 3 common species on the ground, 4 on tree-bases, 6 on midboles, and 13 in the canopy. The members of these assemblages can be characterized as the dominants of these communities. Although inferential limitations prevent us from concluding that these species could be expected to be found in similar Ozark forests with a given certainty, investigators working in the Missouri Ozarks in the future would be advised to be prepared to deal substantially with these species. It is important to note, however, that we are not able to draw any conclusions as to the ecological relatedness of these species to one another: patterns of co-occurrence give no indications as to underlying processes.

No associations were seen in any habitat between the identified lichen assemblages and lichen physiognomy (MRPP, all p's >0.1) or nitrogen fixing capability (MRPP, all p's >0.1). These lichen assemblages cut across morphological categories, reflecting the evolution of these morphologies to adapt to the various microhabitats available in hardwood forests. The low association with nitrogen fixing capability reflects the few species with this capability and their relative scarcities.

Habitat and Substrate Relations

Significant variation in relative species composition and abundance for the full lichen community was observed among the four habitat types (MRPP $p < 0.001$) and is attributable to a large number of species demonstrating habitat preferences for a given habitat (Table 1). Although nearly 70 species were most common and abundant in a single habitat (as shown in Table 1), more than 20 species had high indicator values (IV) for both the base and the midbole tree habitat. Ten additional species showed a preference for both midboles and canopies, while a handful of species

were found only as epiphytes (i.e., *somewhere* on a tree), but did not demonstrate a preference for a particular tree habitat.

Ground Substrates

Fully 54% of samples were considered to have originated as litterfall, involving 69 of the 181 lichen species. Of the 6 substrate classes, 50% (69 taxa) were either free or on undecayed twigs and pinecones, 33% (80 taxa) were on undecayed wood, and 12% (49 taxa) on stone. Of the 10 substrate classes, 41% of samples and a total of 67 taxa were found on twigs, 19% (62 taxa) on bark and 11% (63 taxa) on branches, with the remainder distributed across the other seven types.

Although sampling was not stratified by ground substrate (and hence unequal sampling probabilities reduce our confidence in statistical tests comparing these groups), a quick look at apparent substrate patterns may help guide future sampling efforts. Relative species composition and abundance varied by substrate (MRPP $p < 0.01$). No species showed a preference (i.e, IV's ~30 higher than for other groups) for soil, while rock substrates were the most typical (or exclusive) host for *Acarospora fuscata*, *Aspicilia caesiocinerea, Buellia spuria, Flavoparmelia baltimorensis, Physcia subtilis*, and *Aspicilia* sp. Downed woody debris was the preferred substrate for *Trapeliopsis flexuosa*, *Tuckermannopsis fendleri*, *Physcia* sp., *Bacidia* sp., *Canoparmelia* sp., and *Pertusaria* sp. In addition, a number of species more typical to midboles were found on wood when they were found on the ground layer, including *Arthonia caesia, Caloplaca cerina*, *Candelariella xanthostigma*, *Lecanora strobilina*, *Maronea polyphaea*, *Parmotrema eurysacum*, *Parmotrema hypotropum*, *Pertusaria pustulata*, and *Canomaculina subtinctoria*. Notable differences could be detected among ground substrates for all of the substrate categories (MRPP all $p < 0.01$), including among stone vs. logs/branches/twigs/free-form specimens, among soil/stone/lignum vs. fresh logs/branches/twigs, and between litterfall and non-litterfall.

The size of downed woody debris also affected lichen community composition (MRPP $p < 0.05$). Breaking downed woody debris on the ground layer into three size classes, *Bacidia polychroa*, and *Tuckermannopsis fendleri* were typically found on twigs, *Graphis scripta* and *Phaeophyscia rubropulchra* on branches, and *Cladonia* squamules and *Trapeliopsis flexuosa* on logs. The following species were more typically found on smaller ground wood (twigs and branches): *Amandinea polyspora*, *Arthonia caesia*, *Hypotrachyna livida*, *Lecanora strobilina*, *Lecidea varians*, *Maronea polyphaea*, *Physcia stellaris*, *Vulpicida viridis*. Larger wood (branches and logs) was inhabited by *Physcia americana*, *Punctelia rudecta*, and *Rimelia reticulata*.

Degree of decay of downed woody debris was also important (MRPP $p < 0.05$). Only *Cladonia* squamules showed a higher indication for more heavily decayed wood (classes 4-5) over less decayed wood (classes 1-3). Numerous species were virtually only found on less decayed wood, most likely representing recent litterfall from the bole or canopy: *Amandinea polyspora*, *Arthonia caesia, Arthothelium taediosum*, *Bacidia schweinitzii*, *Buellia stillingiana*, *Caloplaca camptidia*, *Candelaria concolor*, *Graphis scripta*, *Heterodermia speciosa*, *Hypotrachyna livida*, *Lecanora caesiorubella prolifera*, *Lecanora hybocarpa*, *Lecidea varians*, *Maronea polyphaea*, *Myelochroa galbina*, *Parmotrema eurysacum*, *Parmotrema hypotropum*, *Pertusaria pustulata*, *Phaeophyscia pusilloides*, *Phaeophyscia rubropulchra*, *Physcia americana*, *Physcia millegrana*, *Physcia*

stellaris, *Punctelia rudecta*, *Pyxine sorediata*, *Pyxine subcinerea*, *Rimelia reticulata*, *Usnea strigosa*, *Vulpicida viridis*, unknown pyrenocarp, and *Canoparmelia* sp..

Host Tree Species

Relative species composition and abundance varied significantly (MRPP $p < 0.001$) among groups of host species as well (Figure 2). *Heterodermia speciosa*, *Pertusaria paratuberculifera*, and *Punctelia rudecta* were more frequent and abundant on trees in the red oak group, while no species showed a preference for the white oak group. The shortleaf pine group, however, was consistently dominated by *Amandinea punctata*, *Canoparmelia caroliniana*, *Canoparmelia texana*, CDmba, CDsqm, *Chaenothecopsis nana*, *Lecanora strobilina*, and *Parmotrema hypotropum*. Hickory was the preferred host for *Arthonia caesia*, *Arthonia dispersa*, *Bacidia schweinitzii*, *Graphis scripta*, *Candelaria concolor*, *Lecanora strobilina*, *Lepraria lobificans*, *Leptogium milligranum*, *Myelochroa aurulenta*, *Opegrapha varia*, *Pertusaria tetrathalamia*, *Phaeophyscia pusilloides*, *Phaeophyscia rubropulchra*, *Physciella melanchra*, *Physcia americana*, *Physcia millegrana*, and *Placidium tuckermanii*. Only *Lecanora caesiorubella prolifera* and *Pertusaria paratuberculifera* showed a preference for dogwood.

Samples were collected from 13 tree species on tree-bases and midboles and from 7 tree species in the canopy. Patterns of tree-base and midbole lichen community associations with environmental variables were largely obscured by a strong separation of the communities occurring on the tree species shortleaf pine, and the white and red oak groups in almost all sites when evaluating each site independently. In the canopy, the variability in tree species from site to site prevented a broad generalization, but clearly within a site more variation was associated with host species than with any other measured environmental variable.

Canopy branches

Relative species composition (presence/absence transformed to minimize surface area effects) of lichens was compared across the four size classes of canopy branches and found to differ significantly (MRPP $p < 0.001$), particularly among the largest and smallest classes. Species most associated (IV's ~30 higher than for other groups) with the smallest branch class were: *Arthonia punctiformis*, *Mycoglaena quercicola*, and unkncr1. Species associated with the next smallest size class were: *Lecidea varians*, *Maronea polyphaea*, *Physcia stellaris*, and *Vulpicida viridis*. The second to largest class was associated with: *Flavoparmelia caperata*, *Hypotrachyna livida*, *Lecanora caesiorubella prolifera*, *Lecanora hybocarpa*, *Maronea polyphaea*, *Parmotrema hypotropum*, *Punctelia rudecta*, and *Pyxine subcinerea*. The largest branches were colonized by: *Buellia stillingiana*, *Canoparmelia texana*, *Flavoparmelia caperata*, *Lecanora hybocarpa*, *Maronea polyphaea*, *Parmotrema perforatum*, *Pertusaria pustulata*, *Punctelia rudecta*, and *Pyxine subcinerea*.

The pattern in branch sizes is most clearly seen in the ordination diagram in Figure 3, where Axis 1 captures the size gradient. A positive association ($r<0.45$) with this Axis (i.e., greater frequency and abundance on larger branches) was seen for *Lecanora caesiorubella prolifera*, *Lecanora hybocarpa*, and *Pyxine sorediata* and a negative gradient (i.e., more on smaller branches) was seen for *Arthonia punctiformis* and *Mycoglaena quercicola*. Occasionally, species typically found in

the canopy were found on the ground in abundance due to litterfall. These included: *Amandinea polyspora*, *Lecanora strobilina*, *Myelochroa galbina*, *Usnea strigosa*, and *Vulpicida viridis*.

Environmental Relations

Site Level
All Sampled Species

Although no significant differences in relative species composition and abundance were observed among sites and blocks for the ground, tree-base, or midbole habitats (MRPP all >0.4), sites in the midbole habitat tended to group together in the ordination diagrams by block and treatment groups (MRPP $p < 0.5$) and in the canopy habitat by treatment groups (MRPP $p < 0.5$; e.g., Figure 4). Site placement for the MOFEP study was conducted independently of lichen communities. Differences in these communities prior to treatment, however, will need to be taken into consideration when analyzing for post-treatment effects by using the control groups and contrasting to pre-treatment data. No such pattern was observed for the ground habitat or tree bases and sample size was too low to permit a test for the canopy habitat for blocks.

The lichen communities of all four habitats were associated with the relative abundance of various oak species, and groups, in the overstory (Table 2). Although tempting to characterize these associations as patterns of contrast among members of the red and white oak groups, they are in fact more complex. There was a general trend for white oak to contrast with scarlet oak (Figure 4), but post oak (Figure 4a), Schumard oak (Figure 4a,c,d), Northern red oak (Figure 4b), and black oak (Figure 4d) often showed differeing patterns from their associate groups.

Typical and Common Assemblages
Once again, no differences in the relative species composition and abundance of lichens among sites or blocks were seen for any habitat when considering only typical and common assemblages (MRPP, all p's >0.1). However, lichen communities continued to be significantly dissimilar by treatment in the midbole ($p=0.01$) and the canopy ($p=0.02$) habitats. Similar patterns were seen for typical and common species as for all sampled species with respect to oak species and oak species groups (Table 3).

For the ground habitat, the typical and common assemblages showed a marked contrast between sites with and without high white oak density and basal area. The following species were positively associated with sites with high scarlet oak density and basal area: *Flavoparmelia baltimorensis*, *Hypotrachyna livida*, *Lecanora hybocarpa*, *Maronea polyphaea*, *Punctelia rudecta*, *Usnea strigosa*, and *Vulpicida viridis* (Figure 5a, Table 4).

For tree-bases, the contrast was between sites with high white oak density and basal area (positively associated with *Bacidia schweinitzii* and *Lepraria* sp. #1) and those with high post oak density and basal area & scarlet oak basal area (positively associated with *Flavoparmelia caperata*, *Loxospora pustulata*, *Pertusaria paratuberculifera*, *Lepraria lobificans*, and *Punctelia rudecta*) (Figure 5b, Table 4).

The tree pattern continued for midbole samples, contrasting sites with and without high black and scarlet oak density and basal area (positively associated with *Lepraria lobificans* and *Phaeophyscia pusilloides* and negatively with *Heterodermia speciosa*). A weaker distinction was

made between sites with (BACSP, *Loxospora pustulata*, *Myelochroa aurulenta*, *Parmotrema hypotropum*, and *Punctelia rudecta*) and without (*Lepraria lobificans*) higher total tree basal area (Figure 5c, Table 4).

The same pattern was observed in the canopy, with higher scarlet oak density and basal area (positively associated with *Arthothelium taediosum*, *Hypotrachyna livida*, *Lecanora hybocarpa*, and *Pertusaria pustulata*) contrasted with higher white oak density and basal area (*Amandinea polyspora*, *Flavoparmelia caperata*, and *Lecidea varians*). A second gradient in the canopy lichens contrasted plots with high (positively associated with *Parmotrema hypotropum*, *Buellia stillingiana*, and *Lecanora strobilina*) and low Schumard oak basal area (associated with *Arthonia punctiformis*; Figure 5d, Table 4).

Subplot Level

Results at the subplot level were virtually identical for all sampled species as for the typical and common species, due to the dominance of the latter. Once again, lichen communities differed by habitats across sites and subplots (MRPP p's <0.05). When examining samples at the subplot level, the lack of pattern across sites is readily evident (Figure 6). At the landscape level, the nine MOFEP plots do not vary sufficiently for the lichen communities found within them to be distinct.

No association with lichen assemblages was seen with ELT-P in the ground habitat, and only weak association in sites 8 and 9 for tree-bases, in sites 1 and 8 for midboles (Figure 7), and in sites 3 and 7 for canopy lichens. In other words, these associations were too weak and inconsistent to be used as a reliable predictor of these lichen assemblages.

However, relatively consistent associations were seen for aspect class, geology, bedrock, landform, and soil for all four habitats, although not always demonstrating the same pattern. On the ground, aspect class and bedrock were most associated with the lichen assemblages. On tree-bases and midboles, aspect class and bedrock were even more important (Figure 7). In the canopy, slope and landform grew in importance. These patterns, however, are all too weak to regress and produce a predictive model. At best, we can recommend that future site selection for studies of these lichen communities should aim to either test the influence of, or control for, these environmental characteristics. Associations with soil may be redundant to those with geology and bedrock.

Lichen Diversity

At the site level, no patterns of association (i.e., correlation) were seen between canopy lichen diversity measures and the measured environmental characteristics (Table 5). In addition, no associations were seen between lichen diversity measures and the white oak group variables for any habitat. However, strong patterns of association were seen with the red oak group variables and individual white and red oak species. Gamma diversity in the ground habitat was positively associated with white oak density (r=0.48), while on tree-bases the positive association was with scarlet oak (r=0.45) and black oak (r=0.48) density. Midbole gamma diversity was positively associated with black oak density (r=0.47) but negatively associated with post-oak density (r=0.48). Alpha diversity in the ground habitat showed a negative association with white oak basal area (r=0.56) but positive associations with the red oak group basal area and density (both r=0.64), due in large part to scarlet oak basal area and density (both r=0.55). Tree-base alpha

diversity was positively associated with the red oak group density (r=0.54), due to black oak (r=0.65) and scarlet oak (r=0.50). The inverse of the Shannon-Weaver diversity index in the ground habitat was negatively associated with overall tree basal area (r=0.46), likely due to white oak basal area (r=0.59), but positively associated with the red oak group basal area (r=0.68) and density (r=0.82) and in particular scarlet oak (r=0.70) and black oak (r=0.55) density. This index was only negatively associated with black oak basal area (r=0.48) on midboles. A negative association on midboles was also seen between black oak basal area and the inverse of Simpson's index (r=0.55). On the ground habitat, this index was negatively associated with white oak basal area (r2=0.56) but positively associated with the red oak group density (r=0.75), due to scarlet oak (r2=0.59) and black oak (r=0.56) densities, and Northern red oak basal area (r=0.55). None-the-less, no strong multiple factor predictive models could be developed. No associations were found between species richness and tree diameter for tree-base or midbole lichens.

Contrasts of mean species richness, gamma diversity, Shannon Diversity, Simpson's Dominance, and evenness among sites, blocks, and treatments showed no significant differences (ANOVA, all $p>0.3$). However, substantial differences were observed for different habitats, substrates, ground wood sizes, ground wood decay classes, and among canopy branch sizes (Table 6,7).

At the subplot level, highly significant associations were observed among gamma diversity, the inverse of the Shannon-Weaver diversity index, and the inverse of the Simpson's Index and ELT-P, geology, slope, aspect, and landform; however, these associations had no predictive ability (all R^2 values < 0.10) and were likely so highly significant due to the large sample size (as an artifact of calculation, statistical significance increases dramatically as sample size increases, regardless of the nature of the underlying relationships). At best, there is suggestive evidence that these features show some association with lichen diversity, but further study would be needed to elucidate these relationships.

Discussion

Perhaps the most important finding of this study has simply been the characterization of an Ozark lichen community at the end of the 20th century. Rather than a cataloguing of long-established taxa in a static ecosystem, our sampling represents more of a snap-shot of communities that may still reflect radical changes in the Missouri landscape since settlement. Far from pristine sites, given the area's history of pre-settlement indigenous use of fire, extensive post-settlement deforestation and conversion to agriculture, and most recently fire suppression (Ladd 1991b), they are none-the-less relatively un-impacted by the smog and pollution that have already seriously impacted lichen communities near urban areas throughout the country (e.g., McCune et al. 1997), which has been held responsible for such low species richness as the 15 species in Indianapolis (McCune 1988) and the barely dozen non-crustose species found in the Ohio River valley (Showman 1990).

Although the species listed in Appendix 1 were previously known for Missouri, their habitat associations, relative frequencies, and relations to environmental conditions were previously unknown not only for the MOFEP sites but for Missouri, the Ozarks, and midcontinental North America in general. Although no other community analysis of Ozark lichens exists for comparison, the species observed in this study are representative of Missouri lichens (Ladd 1991a,

1996, 2002). Despite a near-complete lack of comparable community studies in the Midwest and neighboring states, general comparisons can be made to lichen communities from other regions. These are among the most diverse lichen communities in the country. Studies of lichen communities in the hardwood dominated landscapes of New England have found highly variable, and notably lower, species richness, ranging from 40 to 136 species (Selva 1994). Community studies conducted in the Pacific Northwest have documented 97 species of epiphytic lichens in a coniferous stand in western Washington (McCune et al. 2000), 35 species of epiphytic macrolichens (i.e., not including crustose species) in comparably-aged stands in western Oregon (Neitlich 1993), and 45 species of macrolichens on old-growth canopy branches in the same region (Sillett 1995). In contrast, a mere 33 species of macrolichens were found in balsam fir stands in New Hampshire (Lang et al. 1980). Compared to the 140+ lichens (60+ of just macrolichens) found epiphytically in this study, we are quickly reminded of the tendency for lichen diversity to be higher in mixed hardwood forests than in conifer forests, particularly those in more northerly or colder climates. This contrast is particularly striking given that broad ocular surveys, such as those used in studies of other regions, are better suited to capturing total diversity that the stratified microplot sampling used in the current study (McCune & Lesica 1992).

Another important finding of this study has been quantitative support for the need to stratify sampling by habitat. In order to effectively evaluate treatment effects resulting from the different harvest methods in the MOFEP study, the within-treatment variation in lichen communities must be as low as possible. Based on the diversity and variability in lichen species composition among the habitats in this study, it will be necessary to continue, and even expand, such stratification when remeasuring to evaluate treatment effects. While fewer lichen species were found on the ground (23) as opposed to tree trunks (50) or canopy branches (45) in Montana (Lesica et al. 1991), the opposite pattern was found in the current study, with species richness decreasing with habitat height above the ground. We hypothesize that this response is due to rapid desiccation from greater aeration in the windy Midwest as you increase in height, a trend that has been documented in other regions (e.g., Szczawinski 1953), and to the extreme habitat variability, and hence niche diversification, on the ground layer in these stands.

That stratification among tree-bases, midboles, and canopy branches would be necessary was anticipated due to differences among these habitats in other regions. Patterns in lichen communities with canopy height, branch size, and host species have been documented for other regions (e.g., McCune et al. 2000). Even variation among branch sizes due to bark characteristics, water flow, age of the substrate, surface area for catching propagules, successional patterns, etc. have been previously observed (Esseen & Renhorn 1995, Sillet et al. 2000). That the ground habitat would be so diverse, and have such a diverse lichen flora, however, indicates that even greater stratification of this habitat among substrates will be necessary in the future, in particular with respect to the treatment of litterfall. McCune & Lesica (1992) noted that variation in data on lichens from the ground habitat is often due to chance encounters of highly specific microsites. Indeed, in this case very unequal sampling of a large number of substrates has led us to believe that the ground flora of lichens in these stands is substantially larger than was observed. Variation among downed woody debris decay conditions may be due to mortality of epiphytic material, bark condition, water retention, substrate stability, invertebrate/small vertebrate disturbance, successional patterns, etc. (Søderstrom 1988). We strongly suspect that the highly desiccating conditions in these Ozark stands, plus the relatively small diameter of the coarse woody debris,

translate into much drier coarse woody debris than in other regions, which may explain the low diversity of epixylic lichens on logs and branches of advanced decay classes.

One potentially positive aspect of the variation in lichens from the ground sampling has been the large amount of litterfall found in ground sampling, as indicated by typically epiphytic species (e.g. *Lecanora strobilina*) found lying on or lightly incorporated into the ground layer on branches, twigs, pinecones, etc. That so much litterfall has been able to recolonize in these stands suggests that retaining mature trees after partial cutting may be able to promote dispersal and help retain lichen diversity, at least among the larger foliose and fruticose species.

This study also determined that identified assemblages of dominant lichens can be used in lieu of the full lichen community to assess responses to environmental characteristics (and presumably treatments) because the rare species in this dataset would provide too little information to determine response patterns and hence would be unable to contribute to our appreciation of treatment differences unless sample sizes were substantially increased. A streamlined approach to remeasurement, in which only the members of these assemblages (identified in Appendix 1) are targeted, would reduce sampling and specimen verification time as well as overall sampling variability. However, such an approach would preclude our ability to evaluate treatment effects upon rare species, which may prove to be the very species that dictate future forest management.

Finally, important patterns of association of lichen species composition and diversity with overstory composition were observed. Dominant lichen species demonstrated either no association or strong positive or negative association with the dominance of red vs. white oak species in the overstory. These patterns, once verified in additional studies, may be used to define ecological assemblages of Ozark lichens as members of red or white group oak communities. These trends also suggest potential patterns of individual lichen distribution throughout Ozarks. Equally importantly, the lack of consistent association with ELT-P suggests that lichen response to these ecological classifications must be explicitly tested if it is desired to use ELT-P as a predictor of lichen communities. Just as understory vegetation is not always tightly associated with ELT-P (Grabner 2002), so too may lichens be less sensitive to the factors defining ELT-P than overstory vegetation. Other environmental variables, such as aspect, slope, and bedrock composition, demonstrated a sufficiently suggestive association with lichen communities that they should be retained in future MOFEP remeasurements.

Based upon these findings, we have developed the following hypotheses to test in Ozark stands, such as those at neighboring Chilton Creek, in future studies:

1. Lichen communities of stands dominated by the red oak group differ substantially and consistently from those found in stands dominated by the white oak group, across all other environmental gradients. This could be tested by contrasting ocular surveys in 10-20 each of red and white oak group dominated stands, across a wide array of other stand and site conditions.
2. Lichen communities demonstrate specificity to host groups more substantially and consistently than they do to individual host tree species for some host groups (e.g., pines, red vs. white oak groups). This could be tested by contrasting the lichen communities in fixed-area microplots on the midboles of 10-20 trees each of each tree species within a given stand.

3. Within a given stand, lichen communities vary minimally among geology, landform, and bedrock. This could be tested by contrasting the lichen communities from ocular surveys in 10-20 plots of varying values for the geology, landform, and bedrock variables.
4. Within a given stand, lichen communities vary minimally with respect to aspect and slope. This could be tested by contrasting the lichen communities of 10-20 stands (of a consistent forest type) of varying aspect and slope values.

If these hypotheses can be tested in nearby areas or within the MOFEP sites and the results applied to the resampling of the MOFEP lichen communities, the sampling effort could be further reduced and the power of the final analyses substantially improved.

Sampling Adequacy

One valuable product of this project has been an estimation of variability in species richness with respect to sampling intensity. Plotting species-accumulation curves is one method to gauge whether or not sample size is adequate (Mueller-Dombois & Ellenberg 1974). These curves plot the number of sample units against the ranked cumulative average species richness per plot and can visually demonstrate at what sample size most of the species had been captured (when the curve begins to reach an asymptote). Error bars help show the potential range. Examining species-area curves at the site level, we quickly see that nine sites do not fully capture the lichen diversity of the Ozark hardwood forests (Figure 8). While that was in fact not the objective of the current study, we can conclude that future studies with such an objective in mind would be well advised to substantially increase the number of sites if using sampling, stratification, and sample sizes similar to the current study.

Looking at species richness at the subplot level, however, it becomes evident that sampling at this scale may have been *just* sufficient to capture most species for all but the ground habitat (Figure 9). From this, a minimum sampling of at least 50 subsamples per $1/20^{th}$ acre plot would be recommended in future studies of tree-base, 40 for midbole lichens, and 30 for canopy branch lichens. Due to the extreme variability in substrates on the ground, ground-based lichen sampling would best be stratified by substrate type before applying this minimum sample size range. Given that this is logistically virtually impossible, subsample sizes should be increased to a minimum of 200-250 per site.

Using a statistically more stringent method, appropriate sample size for similar future studies can be calculated using power analysis based on the current data and a couple of basic assumptions. If species richness is our desired response variable, we can calculate the mean and variance of species richness for each habitat and, based on these values, decide that we wish our future sampling to provide estimates of mean species richness that vary by no more than, say, 20% from the actual mean. If we further assume that a 90^{th} percentile confidence interval is sufficient, we can use the following equation to calculate desired sample size for each habitat:

$$n = \frac{t^2 * s_y^2}{E^2} \qquad \text{e.g., } n = \frac{1.645^2 * 28.2^2}{5.72^2} = 66 \qquad \text{Equation 3}$$

where the value of t comes from the 90^{th} percentile of the t distribution, s_y is the observed population variance from our study (here shown for site-level ground lichens), and E is 20% of the

observed mean from our study (Freese 1962). This method takes into account the actual observed variation in species richness from site to site and subsample to subsample. Using this method, we discover that substantially larger sample sizes are called for, roughly on the order of 86-95% more sites and 77-98% more subsamples than were used in the current study. At the site level, recommended sampling sizes for ground, tree-base, midbole, and canopy sampling are 66, 109, 191, and 52, respectively. At the subsample level, recommended sample sizes are 346, 377, 1407, and 33, respectively. Although the extremely high sample size for midboles at first seems anomalous, closer inspection revealed phenomenally high variation in sample species richness for this habitat, whereas canopy branches were found to be very homogeneous. The most practical approach to future sampling may be further stratification to reduce this variation. Tree-base and midbole sampling should be stratified by host tree species and ground sampling by substrate type (e.g., rock vs. wood).

Based on jacknife estimates of species richness, roughly 74% of the species present in these communities were captured by the subsampling, averaging across habitat types. This would actually be lower (244 species) than the roughly 291 species observed in floristic surveys of these MOFEP sites (D. Ladd, pers. comm.). It is impossible for any subsampling technique to fully capture all species present in a community. Estimates by McCune & Lesica (1992) of accuracy of species richness estimates from microplot vs. whole plot ocular surveys (based on total species lists from combined methods) demonstrated that ground microplots captured 49% of species, midbole microplots 64%, and low canopy branch microplots 77%. However, microplots were demonstrated to be the best sampling strategy when trying to capture treatment effects, as is ultimately the objective with this study. If, when these MOFEP plots are resampled post-treatment, a full characterization of the lichen community is desired, the addition of whole-plot ocular surveys is recommended.

On an additional note, should future studies be concerned with diversity comparisons, it is imperative that sampling be conducted on a standard-area basis. Diversity indices, including simple counts of species richness, are positively proportionally related to the area measured. In this particular study, actual area measured varied among substrates per habitat (e.g., a $0.25m^2$ quadrat was used for ground sampling, but the actual area per substrate (rock, twigs, logs) was not recorded), making some comparisons invalid.

Recommendations

The following recommendations are put forth for application to future lichen community sampling in the established MOFEP sites or for other studies in the Missouri Ozarks:

1. For estimating treatment effects, remeasurements should follow the same sampling methodology used in 1996 with these modifications:
2. Future canopy sampling should be stratified by host tree species.
3. Based on the frequency of ground substrate types, substrate classifications could be reduced to soil, rock, undecayed (1-3) twigs, decayed (4-5) twigs, undecayed (1-3) branches, decayed (4-5) branches, undecayed (1-3) logs, decayed (4-5) logs, and miscellaneous wood.

4. If taxonomic skill or time is limiting for estimating treatment effects, sampling may focus exclusively on the "typical" and "common" species identified in this report. Doing so will preclude evaluations of impacts on rare species or aggregate lichen biodiversity. However, power for evaluating impacts on rare species may in any case be low unless sample sizes are many times higher than in the pre-treatment sampling.
5. For more fully characterizing the lichen community of the Missouri Ozarks in future studies, subplot ocular surveys should be conducted.

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Literature Cited

Beals, E. 1984. Bray-Curtis Ordination: An effective strategy for analysis of multivariate ecological data. IN A. Macfadyen & E. Ford (eds.) Advances in Ecological Research 14.

de Wit, T. 1983. Lichens as indicators of air quality. Environmental Monitoring and Assessment 3:273-282.

Dettki, H., P. Klintberg, & P.-A. Esseen. 2000. Are epiphytic lichens in young forests limited by local dispersal? Ecoscience 7(3):317-325.

Dufrene, M. & P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67:345-366.

Esseen, P.-A. & K. Renhorn. 1998. Edge effects on an epiphytic lichen in fragmented forests. Conservation Biology 12(6):1307-1317.

Esseen, P.-A., K. Renhorn, & R. Pettersson. 1996. Epiphytic lichen biomass in managed and old-growth boreal forests: effect of branch quality. Ecological Applications 6(1):228-238.

Freese, F. 1962. Elementary Forest Sampling. Agricultural Handbook 232, U.S.D.A. F.S. Southern Forest Experiment Station.

Gauch, H. 1982. Multivariate Analysis in Community Ecology. Cambridge University Press.

Glenn, M., S. Webb, R. Turk, & R. Zores. 1997. Lichens as indicators of forest integrity. Progress and problems in lichenology in the nineties. Proceedings of the Third Symposium of the International Association for Lichenology, University of Salzburg, Austria, 1-7 September 1996. Bibliothecal-Lichenolgoical 68:155-164.

Grabner, J. 2002. Patterns in upland forest vegetation in relation to geology, topography, and soils: an approach to ecological land classification in the southeast Missouri Ozarks. MS thesis, University of Missouri—Columbia.

Hale, M.E. 1965. Vertical distribution of cryptogams in a red maple swam in Connecticut. The Bryologist 68:193-197.

Hale, M.E. 1979. How to know the lichens, 2nd edition. Wm. C. Brown Co., Dubuque, IA.

Hilmo, O. 1994. Distribution and succession of epiphytic lichens on *Picea abies* branches in a boreal forest, Central Norway. Lichenologist 26(2):149-170.

Hoffman, G. & R. Kazmierski. 1969. An ecologic study of epiphytic bryophytes and lichens on *Pseudotsuga menziesii* on the Olympic Peninsula, Washington I. Description of the vegetation. The Bryologist 72:1-19.

Jensen, R. 1993. MOFEP overstory data collection procedures. Missouri Department of Conservation. Jefferson City, MO. 32 p.
Jesberger, J. & J. Sheard. 1973. A quantitative study and multivariate analysis of corticolous lichen communities in the southern boreal forest of Saskatchewan. Canadian Journal of Botany 51:185-201.
Knops, J., T. Nash III, & W. Schlesinger. 1996. The influence of epiphytic lichens on the nutrient cycling of an oak woodland. Ecological Monographs 66(2):159-179.
Ladd, D. 1991a. Preliminary list of the rare and endangered macrolichens of Missouri. Transactions, Missouri Academy of Science 25(1):5-12.
Ladd, D. 1991b. Reexamination of the role of fire in Missouri oak woodlands. Pages 67-80 in Proceedings of the Oak Woods Management Workshop, Eastern Illinois University, Charleston, IL.
Ladd, D. 1993. Conservation of bryo-lichen biodiversity: a Missouri perspective. American Journal of Botany 80(6 supp.):5. [abstract]
Ladd, D. 1996. Lichen assessment and monitoring in two oak woodlands, Mark Twain National
Forest, Missouri. Final Report, USDA Forest Service Contract 40-64R7-3-50. 68 pp.
Ladd, D. 1998. Looking at Lichens. Missouri Conservationist 59(10): 8-13.
Ladd, D. 2002. Lichens of the lower Ozark region of Missouri and Arkansas. Missouri Botanical Garden/Nature Conservancy Report to the Missouri Department of Conservation. 139 pp.
Ladd, D. & J. Grabner. 1996. Lichen species composition in the Southeastern Ozarks. A progress report of work completed submitted to the Missouri Department of Conservation, MOFEP.
Ladd, D. & J. Grabner. 1998. The MOFEP lichen project: profiling the lichen vegetation of the Ozark highlands. 1998 American Bryological and Lichenological Society, June 11-16 1998, San Juan, Puerto Rico. [abstract]
Ladd, D., N. Morin, J. Grabner, & G. Waller. 1996. Lichen species composition in the Southeastern Ozarks. A research proposal submitted to the Missouri Department of Conservation, MOFEP.
Lang, G., W. Reiners, & L. Pike. 1980. Structure and biomass dynamics of epiphytic lichen communities of balsam fir forests in New Hampshire. Ecology 61(3):541-550.
Lesica, P., B. McCune, S. Cooper, & W. Hong. 1991. Differences in lichen and bryophyte communities between old-growth and managed second-growth forests in the Swan Valley, Montana. Canadian Journal of Botay 69:1745-1755.
McCune, B. 1988. Lichen communities along O3 and SO2 gradients in Indianapolis. The Bryologist 91(3):223-228.
McCune, B. & J. Antos. 1982. Epiphyte communities of the Swan Valley, Montana. The Bryologist 85:1-12.
McCune, B. & P. Lesica. 1992. The trade-off between species capture and quantitative accuracy in ecological inventory of lichens and bryophytes in forests in Montana. Bryologist 95(3):296-304.
McCune, B. & J. Mefford. 1999. Multivariate Analysis of Ecological Data, PC-ORD Vers. 4.01. MjM Software, Glenedon Beach, OR.
McCune, B., J. Dey, J. Peck, K. Heiman, & S. Will-Wolf. 1997. Regional gradients in lichen communities of the southeastern United States. Bryologist 100(2):145-158.
McCune, B., R. Rosentreter, J. Ponzetti, & D. Shaw. 2000. Epiphyte habitats in an old conifer forest in western Washington, USA. Bryologist 103(3):417-427.

McCune, B. et al. 1997a. Vertical profile of epiphytes in a Pacific Northwest old-growth forest. Northwest Science 71(2):145-152.
McCune, B., J. Dey, J. Peck, K. Heiman, & S. Will-Wolf. 1997b. Regional gradients in lichen communities of the southeast United States. The Bryologist 100(2):145-158.
Meinert, D., Nigh, T. & J. Kabrick. 1997. Landforms, geology, and soils of the MOFEP study area. Pages 56-68 *in* Proceedings of the Missouri Ozark Forest Ecosystem Project Symposium: an experimental approach to landscape research. June 3-5, St. Louis, MO. Gen. Tech. Rep. NC-193, USDA FS North Central Forest Experiment Station, St. Paul, MN.
Miege, D., Goward, T., Waterhouse, M. & H. Armleder. Impact of partial cutting on lichen diversity in lodgepole pine forests on the Chilcotin Plateau of British Columbia. Working Paper, Ministry of Forests Research Program, British Columbia. No. 55, vi, 20 pp.
Mielke, P., K. Berry & G. Brier. 1981. Applications of multi-response permutation procedures for examining seasonal changes in monthly sea-level pressure patterns. Monthly Weather Review 109:120-126.
Mueller-Dombois, D. & H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. New York.
Neitlich, P. 1993. Lichen abundance and biodiversity along a chronosequence from young managed stands to ancient forest. Masters Thesis report, Department of Botany, University of Vermont. Burlington, VT. 90 pp.
Nilsson, S. U. Arup, R. Baranowski, & S. Ekman. 1995. Tree-dependent lichens and beetles as indicators in conservation forests. Conservation Biology 9(5):1208-1215.
Peterson, E. & B. McCune. 2001. Diversity and succession of epiphytic macrolichen communities in low-elevation managed conifer forests in Western Oregon. Journal of Vegetation Science 12(4):511-524.
Pettersson, R. 1997. Lichens, invertebrates and birds in spruce canopies: impacts of forestry. Sylvestria 16.
Pettersson, R., K. Renhorn, P.-A. Esseen, & K. Sjöbert. 1995. Invertebrate communities in boreal forest canopies as influenced by forestry and lichens with implications for passerine birds. Biological Conservation 74:57-63.
Pharo, E. & D. Vitt. 2000. Local variation in bryophyte and macro-lichen cover and diversity in montane forests in western Canada. The Bryologist 103(3):455-466.
Pike, L. 1978. The importance of epiphytic lichens in mineral cycling. The Bryologist 81:247-257.
Pike, L., W. Denison, D. Tracy, M. Sherwood, & F. Rhoades. 1975. Floristic survey of epiphytic lichens and bryophytes growing on old-growth conifers in western Oregon. The Bryologist 78:389-402.
Rosentreter, R., Schneidegger, C., Wolseley, P. and G. Thor. 1995. Conservation biology of lichenised fungi. Mitteilungen der Eidgenossischen Forshungsanstalt für Wald, Schnee, und Landschaft. 70(1):103-124.
Schmitt, D. & N. Slack. 1990. Host specificity of epiphytic lichens and bryophytes: A comparison of the Adirondack Mountains (New York) and the Southern Blue Ridge Mountains (North Carolina). The Bryologist 93:257-274.
Selva, S. 1994. Lichen diversity and stand continuity in the northern hardwoods and spruce-fir forests of northern New England and western Brunswick. The Bryologist 97(4):424-429.
Shannon, C. & W. Weaver. 1949. The Mathematical Theory of Communication. Urbana: University of Illinois Press.

Sharnoff, S. 1994. Use of lichens by wildlife in North America. Research and Exploration 10(3):370-371.

Sheriff, S. 2002. Missouri Ozark Forest Ecosystem Project: The Experiment. Pages 1-25 *in* Kabrick, J., Shifley, S. (eds.) Proceedings of the 27th Annual Natural Areas Association Conferneces: Post-treatment results from the Missouri Ozark Forest Ecosytem Project. October 16-20, St. Louis, MO. Gen. Tech. Rep. NC-227, USDA FS North Central Forest Experiment Station, St. Paul, MN.

Shifley, S., & B. Brookshire, eds. 2000. Missouri Ozark Forest Ecosystem Project: site history, soils, landforms, woody and herbaceous vegetation, down wood, and inventory methods for the landscape experiment. Gen. Tech. Rep. NC-208. St. Paul, MN: U.S.D.A., F.S., North Central Research Station. 314 p.

Showman, R. 1975. Lichens recolonization following air quality improvement. The Bryologist 84:492-497.

Showman, R. 1990. Lichen recolonization in the upper Ohio River valley. The Bryologist 93(4):427-428.

Sillett, S. 1995. Branch epiphyte assemblages in the forest interior and on the clearcut edge of a 700-year-old Douglas fir canopy in western Oregon. Bryologist 98(3):301-312.

Sillett, S., B. McCune, J. Peck, T. Rambo, & A. Ruchty. 2000. Dispersal limitations of epiphytic lichens result in species dependent on old-growth forests. Ecological Applications 10(3):789-799.

Simpson, E. 1949. Measurement of diversity. Nature 163: 688.

Søderstrom, L. 1988. Sequence of bryophytes and lichens in relation to substrate variables of decaying coniferous wood in Northern Sweden. Nordic Journal of Botany 8(1):89-97.

Sokal, R. & F. Rohlf. 1981. Biometry. San Francisco.

Sørensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species content, and its application to analysis of the vegetation on Danish commons. Biol. Skr. 5:1-34.

Stevenson, S. 1978. Distribution and abundance of arboreal lichens and their use as forage by blacktailed deer. M.S. Thesis, University of British Columbia, Vancouver.

Szczawinski, A. 1953. Corticolous and lignicolous communities in the forest associations of the Douglas-fir forest on Vancouver Island. Ph.D. dissertation, University of British Columbia, Vancouver.

Table 1. Indicator Values for lichen species across the four habitat types. Indicator Values suggest the degree of indication of a given species for a given group and are calculated as the product of the relative frequency and abundance of a given species in a given group. Values ~30 higher than for other groups suggest group preference. P-values test the significance of a strong preference for a single group.

	Ground	Tree-base	Midbole	Canopy	p		Ground	Tree-base	Midbole	Canopy	p
ACAFU	44	0	0	0	0.010	OCHAF	2	0	21	24	0.335
AGOSP1	0	55	0	0	0.004	OPEBR	0	6	17	0	0.391
AMAPO	11	0	1	84	0.001	OPEVA	0	28	33	0	0.210
AMAPU	0	23	21	0	0.264	PARAU	22	0	0	0	0.209
ANINY	0	71	4	0	0.004	PAREU	33	2	48	1	0.092
ARTCA	22	2	25	47	0.048	PARGA	0	5	0	10	0.567
ARTDI	0	6	10	0	0.728	PARHYPT	5	37	11	38	0.691
ARTPU	0	0	0	100	0.001	PARMIC	4	3	1	8	0.895
ARTPY	0	0	78	5	0.001	PARMIN	1	47	16	1	0.047
ARTSP	7	0	0	6	1.000	parnis	0	0	0	99	0.001
ARTspp	5	0	9	0	0.810	PARPE	1	0	0	98	0.001
ARTTA	1	0	27	72	0.002	PERAM	0	3	80	4	0.001
ASPCS	56	0	0	0	0.003	PERHY	0	0	9	27	0.269
ASPspp	56	0	0	0	0.003	PERNE	1	10	0	0	0.847
BACPO	2	66	27	0	0.038	PEROS	0	68	28	0	0.001
BACSC	1	61	38	0	0.009	PERPA	0	65	32	2	0.004
BACspp	33	0	0	0	0.054	PERPR	0	0	44	21	0.017
BACSU	0	11	17	1	0.594	PERPU	2	2	41	53	0.055
BUESP	89	0	0	0	0.001	PERspp	89	0	0	0	0.001
BUEspp	44	0	0	0	0.017	PERSU	0	1	56	10	0.009
BUESTL	6	2	36	55	0.011	PERTET	0	8	54	0	0.013
CALBR	0	2	2	35	0.060	PERTEX	0	5	76	10	0.001
CALCA	1	17	76	1	0.001	PERTR	0	0	4	91	0.001
CALCE	10	3	54	1	0.008	PERVA	0	11	30	0	0.152
CALFLV	22	0	0	0	0.230	PERVE	0	5	73	3	0.002
CALPO	5	0	47	0	0.006	PHAAD	0	11	0	0	0.840
CANCA	0	22	0	0	0.187	PHACE	0	0	33	0	0.046
CANCO	2	14	81	1	0.001	PHAHIRS	11	0	0	0	1.000
CANRE	0	0	1	78	0.001	PHAPO	1	9	11	0	0.614
CANTE	0	5	11	63	0.003	PHAPU	3	31	60	3	0.001
CANXA	15	3	75	0	0.001	PHARU	2	58	39	0	0.017
CDGRA	0	89	0	0	0.001	PHASQ	0	33	0	0	0.044
CDMABA	0	41	1	0	0.029	PHLAR	22	0	0	0	0.248
CDPEZ	0	89	0	0	0.001	PHYAM	1	28	70	0	0.001
Cdsqm	6	78	16	0	0.001	PHYCH	0	0	3	13	0.383
Cdsqmf	36	6	0	0	0.137	PHYDE	0	17	46	0	0.017
CHANA	0	23	21	0	0.209	PHYME	0	1	21	0	0.401
CNOspp	56	0	0	0	0.003	PHYMI	11	2	58	12	0.021
COCPA	4	28	0	0	0.110	PHYPU	0	1	8	63	0.004
COLCON	0	13	9	0	0.559	PHYspp	56	0	0	0	0.004
COLFUR	0	86	13	0	0.001	PHYST	30	1	10	59	0.001
DIMSP	0	17	5	0	0.400	PHYSU	78	0	0	0	0.001
ENDPU	2	19	0	0	0.225	PLATU	0	23	26	0	0.235

Table 1 continued.

	Ground	Tree-base	Midbole	Canopy	p		Ground	Tree-base	Midbole	Canopy	p
FLABA	76	3	0	0	0.001	PUNRU	4	25	51	19	0.001
FLACA	5	21	40	35	0.087	PUNSU	0	3	0	23	0.109
GRASC	7	3	89	0	0.001	PYRCA	0	0	0	33	0.031
HETGR	0	21	1	0	0.300	PYRPS	1	0	97	0	0.001
HETHY	0	1	27	2	0.090	PYXSO	1	23	62	7	0.002
HETOB	0	28	70	0	0.001	PYXSU	3	5	44	47	0.026
HETSP	0	83	17	0	0.001	RAMAM	2	0	40	0	0.018
HYPLI	9	0	9	79	0.001	RAMAML	0	0	0	33	0.033
JULFA	0	2	71	3	0.003	RIMCE	1	0	12	14	0.469
LECCAPR	5	1	23	69	0.002	RIMRE	2	31	36	18	0.507
LECHY	6	3	32	59	0.001	RIMSU	12	0	9	0	0.912
LECspp	0	33	0	0	0.052	RIMSUT	0	63	31	0	0.005
LECST	14	5	11	70	0.001	RINAP	0	1	1	25	0.200
LECVA	2	0	1	96	0.001	RINSU	0	18	7	5	0.326
LEPAU	0	72	2	0	0.001	ROBPU	0	0	33	0	0.076
LEPCY	0	82	5	0	0.001	STRJA	0	33	0	0	0.047
LEPDA	0	44	0	0	0.012	THEFL	0	17	14	0	0.666
LEPLO	1	80	17	0	0.001	TRAFL	40	7	3	0	0.055
LEPMI	0	44	45	0	0.059	TUCFE	64	0	0	5	0.003
LEPsp1	0	46	45	1	0.044	unkcr1	16	15	18	31	0.675
LEPspp	11	0	0	0	1.000	unkcr2	0	1	30	1	0.276
LOXPU	2	17	73	4	0.001	unkfo1	2	18	0	0	0.207
MARPO	11	1	18	68	0.001	unkpy	64	4	1	0	0.001
MYCAL	22	0	0	0	0.218	USNST	14	1	5	78	0.001
MYCPY	0	0	20	31	0.169	VULVI	17	0	0	82	0.001
MYCQU	0	0	0	83	0.001	XANSU	22	0	0	0	0.219
MYEAU	2	43	54	1	0.002						
MYEGA	8	0	8	81	0.001						

Table 2. Correlation coefficients for the association between oak species and species groups and the primary polar ordination axes for ground, tree-base, midbole, and canopy lichens, corresponding to Figure 4. BA=basal area.

	Ground		**Tree-bases**		**Midboles**		**Canopy**	
	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
Post oak BA	-0.50	-0.05	0.17	-0.14	0.22	0.26	-0.06	0.02
Post oak density	-0.71	0.05	-0.07	0.04	0.36	0.20	-0.47	0.05
White oak BA	0.77	-0.21	0.47	-0.07	-0.55	-0.04	0.84	0.01
White oak density	0.56	0.17	-0.16	-0.43	-0.18	-0.04	0.41	-0.40
White oak group BA	0.44	-0.26	0.64	-0.31	-0.35	0.43	0.83	0.00
White oak group density	-0.60	0.36	-0.45	-0.20	0.42	0.27	-0.16	0.26
Black oak BA	-0.15	0.00	-0.30	0.07	0.22	0.21	0.10	0.66
Black oak density	-0.04	-0.14	-0.31	-0.33	0.07	0.42	-0.12	0.43
Northern red oak BA	0.14	0.12	0.13	0.68	0.21	0.23	0.10	0.24
Northern red oak density	0.13	0.32	-0.20	0.60	0.30	0.05	0.03	-0.06
Scarlet oak BA	-0.88	0.49	-0.71	0.38	0.63	-0.24	-0.93	-0.08
Scarlet oak density	-0.38	0.27	-0.66	-0.12	0.28	0.08	-0.86	-0.20
Schumard oak BA	-0.40	0.72	-0.60	0.02	0.74	-0.40	-0.21	-0.86
Schumard oak density	0.27	0.49	-0.51	-0.32	0.15	-0.64	-0.11	-0.73
Red oak group BA	-0.81	0.34	-0.65	0.25	0.64	0.13	-0.83	0.26
Red oak group density	-0.58	0.08	-0.51	-0.10	0.33	0.28	-0.76	0.22
Total BA	0.49	-0.02	0.13	0.15	1.00	2.00	0.33	-0.27
Total Density	0.83	-0.05	0.03	-0.44	-0.40	-0.25	0.37	-0.68

Table 3. Correlation coefficients for the association between oak species and species groups and the primary polar ordination axes for ground, tree-base, midbole, and canopy typical and common lichens, corresponding to Figure 5. BA=basal area.

	Ground		**Tree-bases**		**Midboles**		**Canopy**	
	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
Post oak BA	-0.50	0.22	-0.56	-0.09	0.28	-0.27	-0.06	0.15
Post oak density	-0.69	0.24	-0.68	-0.18	0.15	-0.36	-0.48	0.10
White oak BA	0.77	-0.34	0.77	-0.05	0.10	0.60	0.85	0.04
White oak density	0.53	0.10	0.30	0.46	0.13	0.17	0.44	-0.46
White oak group BA	0.42	-0.14	0.27	0.04	0.58	0.37	0.84	0.13
White oak group density	-0.67	0.56	-0.39	0.35	0.47	-0.48	-0.18	0.13
Black oak BA	-0.28	0.06	-0.03	0.45	0.07	-0.48	0.07	0.59
Black oak density	-0.17	-0.05	-0.25	0.68	0.13	-0.33	-0.13	0.39
Northern red oak BA	0.22	-0.08	0.31	-0.32	0.23	0.05	0.10	0.23
Northern red oak density	0.22	0.04	0.09	-0.27	0.10	-0.10	0.05	-0.06
Scarlet oak BA	-0.79	0.42	-0.69	-0.30	-0.21	-0.51	-0.94	-0.17
Scarlet oak density	-0.37	0.20	-0.52	0.22	-0.01	-0.28	-0.85	-0.32
Schumard oak BA	-0.40	0.84	-0.51	0.17	-0.04	-0.82	-0.18	-0.91
Schumard oak density	0.29	0.42	-0.01	0.32	-0.41	-0.18	-0.08	-0.81
Red oak group BA	-0.82	0.39	-0.62	0.11	0.04	-0.65	-0.84	0.14
Red oak group density	-0.63	0.15	-0.62	0.29	0.06	-0.44	-0.77	0.15
Total BA	0.55	-0.26	0.54	-0.40	-0.53	0.44	0.33	-0.26
Total density	0.84	-0.19	0.33	0.31	-0.25	0.38	0.40	-0.64

Table 4. Correlation coefficients for the association between typical and common lichen species and the primary polar ordination axes for ground, tree-base, midbole, and canopy habitats, corresponding to Figure 5. Only species with correlations r>0.45 are shown.

	Ground		**Tree-bases**		**Midboles**		**Canopy**	
	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2	Axis 1	Axis 2
AMAPO	-	-	-	-	-	-	0.98	0.35
ARTCA	0.20	-0.40	-	-	-	-	0.13	0.04
ARTPU	-	-	-	-	-	-	0.62	0.73
ARTTA	-	-	-	-	-	-	-0.92	-0.65
BACSC	-	-	-	-	-0.66	0.29	-	-
BUESTL	-0.59	0.05	-	-	-	-	-0.44	-0.90
CANTE	-	-	-	-	-	-	0.10	-0.48
FLABA	-0.90	0.70	-	-	-	-	-	-
FLACA	-0.03	0.79	-0.72	0.03	-0.35	-0.71	0.86	0.05
HETSP	-	-	-0.46	0.16	-0.50	0.50	-	-
HYPLI	-0.86	0.66	-	-	-	-	-0.84	-0.36
LECCAPR	-	-	-	-	-	-	-0.63	0.51
LECHY	-0.93	0.47	-	-	-	-	-0.89	-0.23
LECST	-	-	-	-	-	-	-0.13	-0.84
LECVA	-	-	-	-	-	-	0.84	0.04
LEPLO	-	-	0.09	-0.94	0.03	-0.56	-	-
LEPSP1	-	-	0.21	0.69	0.00	0.37	-	-
LOXPU	-	-	-0.64	-0.16	-0.66	0.16	-	-
MARPO	-0.75	0.36	-	-	-	-	-0.60	0.10
MYEAU	-0.06	0.43	-0.35	0.15	-0.65	0.12	-	-
MYEGA	-0.22	-0.16	-	-	-	-	0.36	0.36
PARHYPT	-	-	-0.39	0.03	-0.73	-0.02	-0.53	-0.95
parnis	-	-	-	-	-	-	-0.10	-0.95
PARPE	-	-	-	-	-	-	-0.42	-0.67
PERPA	-	-	-0.78	-0.12	-0.26	-0.06	-	-
PERPU	-	-			-	-	-0.76	-0.55
PHAPU	-	-	-0.57	0.03	-0.32	-0.61	-	-
PHARU	-	-	0.36	0.02	-0.13	0.52	-	-
PHYAM	-	-	-0.35	0.56	-	-	-	-
PHYST	-0.01	0.50	-	-	-	-	0.63	-0.17
PUNRU	-0.80	0.78	-0.66	0.47	-0.74	0.35	0.48	0.20
PYXSU	-	-	-	-	-	-	0.10	-0.35
unkcr1	-0.68	0.42	-	-	-	-	0.12	0.13
USNST	-0.90	0.56	-	-	-	-	-0.24	-0.65
VULVI	-0.82	0.45	-	-	-	-	0.01	0.17

Table 5. Diversity indices by habitat across sites. n = sample size; γ = species richness; α = average species per sample; H' = inverse of the Shannon-Weaver Index; D' = inverse of the Simpson index.

Site		Ground ($0.25m^2$)	Tree-Base ($0.25m^2$)	Tree Midbole ($0.25m^2$)	Canopy (variable area)
All	n	999	435	434	283
	γ	107	122	118	82
	α-site	57.1	56.6	67.6	45.3
	α-plot	4.6	6.8	9.2	8.9
	n	118	60	61	-
	γ	54	40	54	-
1	α	5.3	7.3	8.6	-
	H'	1.28	1.064	1.18	-
	D'	0.625	0.474	0.511	-
	n	111	55	53	48
	γ	62	39	59	30
2	α	4.4	6.4	11.1	9.6
	H'	1.197	1.103	1.581	1.619
	D'	0.605	0.523	0.697	0.701
	n	120	52	52	48
	γ	64	34	51	40
3	α	4.4	5.5	7.4	8.3
	H'	1.07	1.142	1.178	1.432
	D'	0.522	0.55	0.562	0.641
	n	109	58	57	46
	γ	63	40	62	31
4	α	4.7	6	8.4	9.5
	H'	1.159	0.876	1.08	1.471
	D'	0.569	0.415	0.482	0.654
	n	101	68	39	46
	γ	57	28	57	30
5	α	4.2	6.2	11.7	7.8
	H'	1.063	1.117	1.652	1.378
	D'	0.555	0.537	0.678	0.629
	n	101	47	47	-
	γ	49	28	49	-
6	α	3.7	4.1	7	-
	H'	0.949	0.792	1.097	-
	D'	0.495	0.406	0.502	-
	n	116	45	45	47
	γ	52	33	46	33
7	α	5.3	7.1	10.5	8.3
	H'	1.297	1.184	1.452	1.417
	D'	0.633	0.536	0.624	0.64

Table 5 continued.

Site		Ground ($0.25m^2$)	Tree-Base ($0.25m^2$)	Tree Midbole ($0.25m^2$)	Canopy (variable area)
	n	117	48	48	-
	γ	54	33	42	-
8	α	5.1	5.9	6.3	-
	H'	1.195	1.021	0.981	-
	D'	0.585	0.502	0.455	-
	n	106	32	32	48
	γ	60	37	47	32
9	α	4.6	8.9	102	8.5
	H'	1.221	1.57	1.716	1.443
	D'	0.611	0.689	0.729	0.638

Table 6. ANOVA tables for diversity measures by habitat and substrate type.

Source	df	MS	*F*	*p*
Habitat				
Gamma	3	1214.8	42.9	0.0001
Error	29	28.3		
Evenness	3	0.012	7.73	0.0006
Error	29	0.002		
Shannon Diversity	3	0.327	13.75	0.0001
Error	29	0.024		
Simpson Dominance	3	0.003	4.84	0.0075
Error	29	0.0007		
Substrate				
Gamma	3	5070.6	152.35	0.0001
Error	45	33.3		
Evenness	3	0.155	6.75	0.0001
Error	45	0.023		
Shannon Diversity	3	8.82	151.78	0.0001
Error	45	0.06		
Simpson Dominance	3	0.601	94.33	0.0001
Error	45	0.007		
Ground Wood Size				
Gamma	2	1011.1	15.57	0.0001
Error	24	65.4		
Evenness	2	0.077	8.16	0.0020
Error	24	0.009		
Shannon Diversity	2	3.22	00.68	0.0003
Error	24	0.28		
Simpson Dominance	2	0.118	6.38	0.0060
Error	24	0.018		
Ground Wood Decay				
Gamma	1	5832.0	481.54	0.0001
Error	16	12.1		
Evenness	1	0.079	4.20	0.0571
Error	16	0.019		
Shannon Diversity	1	16.10	163.86	0.0001
Error	16	0.09		
Simpson Dominance	1	0.531	31.88	0.0001
Error	16	0.017		
Canopy Branch Size				
Gamma	3	438.2	22.39	0.0001
Error	20	19.6		
Evenness	3	0.016	7.70	0.0013
Error	20	0.002		
Shannon Diversity	3	1.078	19.06	0.0001
Error	20	0.056		
Simpson Dominance	3	0.024	12.07	0.0001
Error	20	0.002		
	3			

Table 7. Mean diversity values by habitat type at the site level. Categories with the same letter are not significantly ($p<0.05$) different. A plus (+) or a minus (-) symbol indicates the direction of difference from the other members of a group.

	Gamma Diversity	**Gamma Diversity**	**Evenness**	**Shannon Diversity**	**Simpson Dominance**
Habitat					
Ground ($0.25m^2$)	57 (6.3)	A	A	A	A
Tree-bases ($0.25m^2$)	57 (7.6)	A	B-	B-	B-
Midboles ($0.25m^2$)	67 (5.3)	B	A	A	A
Canopy (variable area)	45 (4.5)	C	A	BC-	AB
Substrate					
Ground soil	2 (0.8)	A	A	A	A
Ground rock	17 (6.9)	B+	B+	B+	B+
Ground wood	50 (4.5)	C+	B+	C+	B+
Ground wood size					
Logs (>2')	19 12.6)	A	A	A	A
Branches (>0.5")	40 (3.2)	B	B+	B+	B+
Twigs (<0.5")	31 (5.1)	B	A	A	AB
Ground wood decay					
Low decay (1-3)	42 (4.6)	A	A	A	A
High decay (4-5)	6 (21.6)	B	A	B-	B-
Canopy branch size					
Tiny (0.5")	17 (5.5)	A	A	A	A
Small (1.5")	27 (3.4)	B	AB	B+	B+
Medium (3.0")	33 (4.7)	B	B+	B+	B+
Large (4.0")	35 (3.2)	C	B+	B+	B+

Figure 1. Example site-level cluster diagram, showing the aggregation of species in the assemblage recognized for the ground habitat in the box.

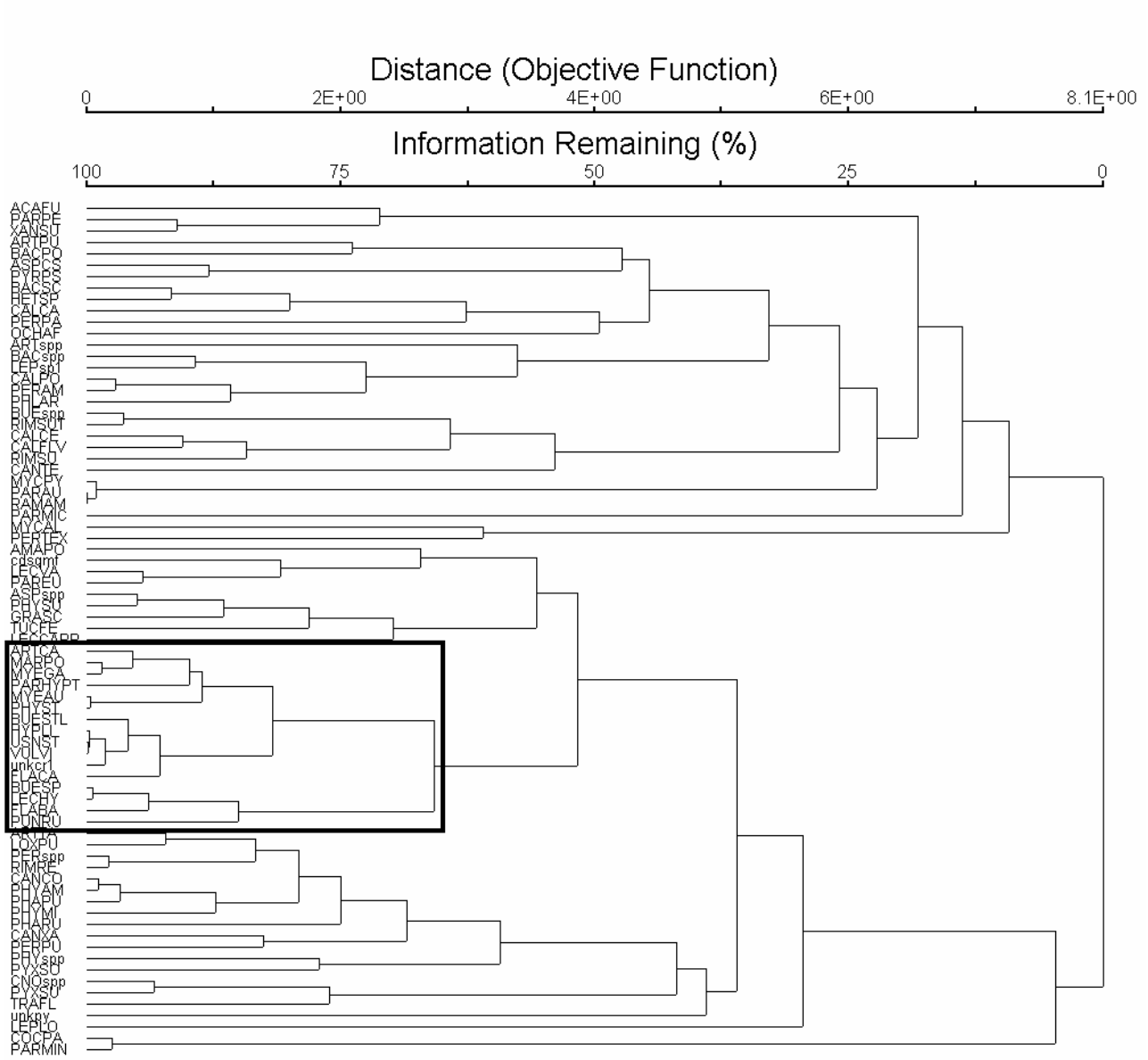


Figure 2. Ordination diagrams showing separation of lichen communities by host tree species group on tree-bases (left), midboles (right), and canopy branches (bottom left).

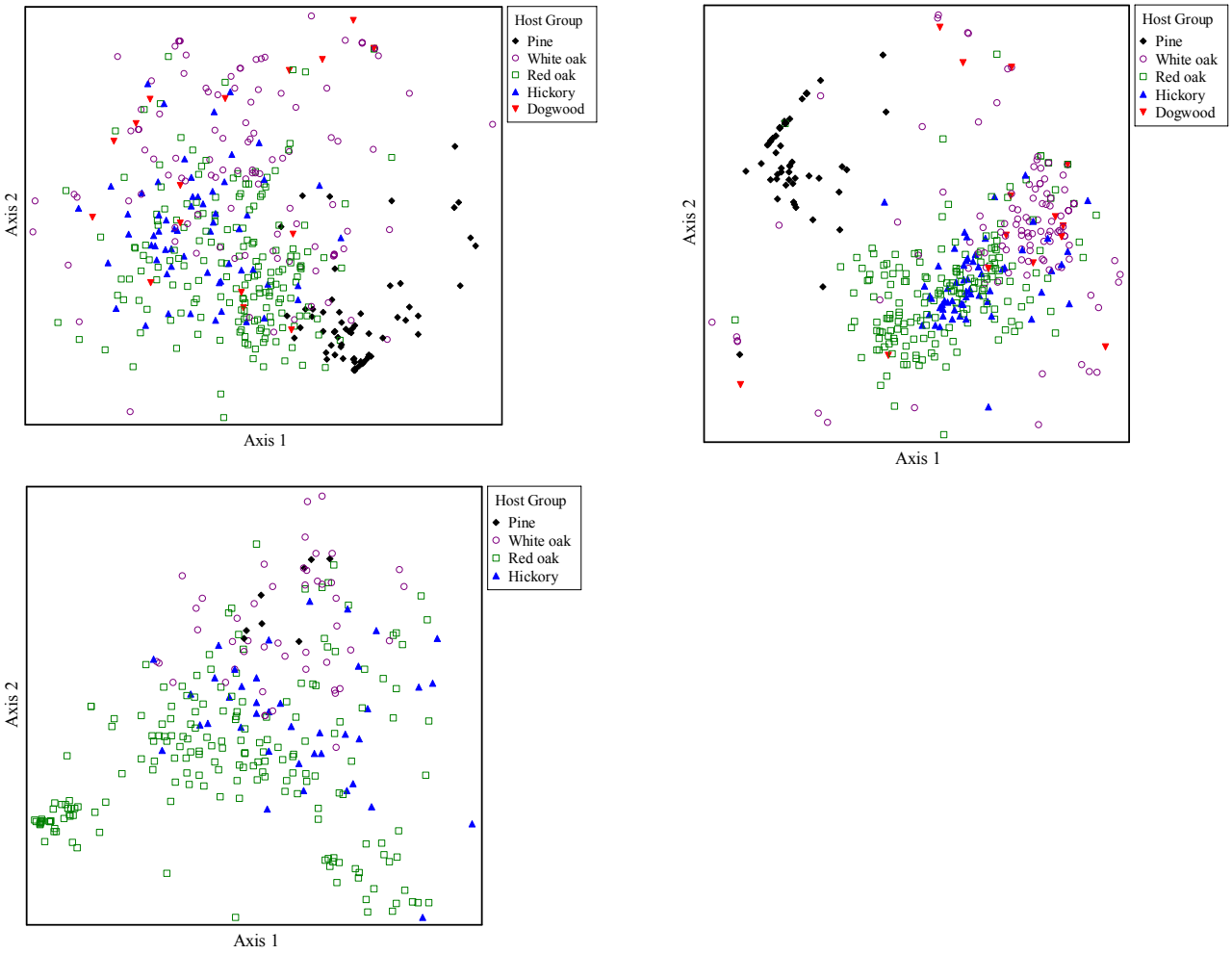


Figure 3. Ordination diagram showing separation of the lichen community by canopy branch size. Variation in branch size is most strongly expressed across Axis 1, although the two largest size classes intermingle and the second to smallest class overlaps with the larger classes.

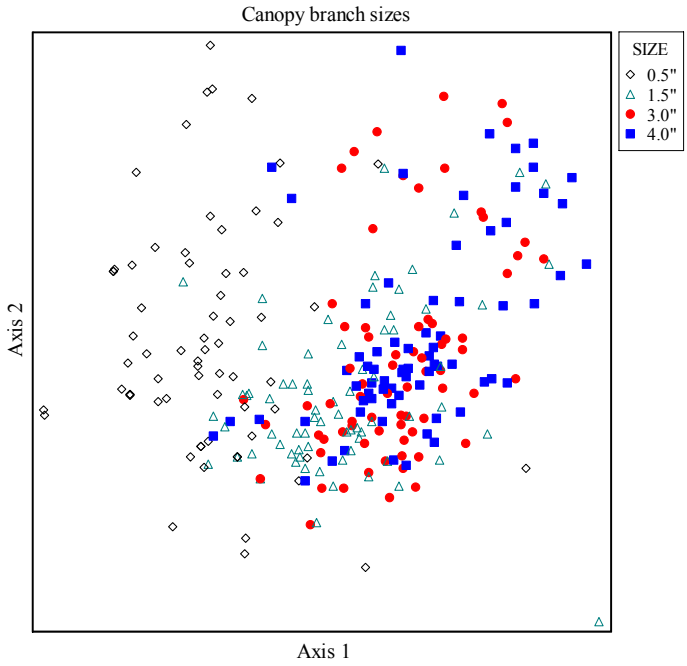


Figure 4. Ordination diagram showing the strong pattern of association of red and white oak density and basal area with the measured lichen communities for the ground, tree-base, midbole, and canopy habitats. The length of the lines is proportional to the magnitude of the correlation of that variable with the ordination axes. All ordinations have been rotated such that white oak basal area (BA) corresponds to Axis 1 to facilitate comparison.

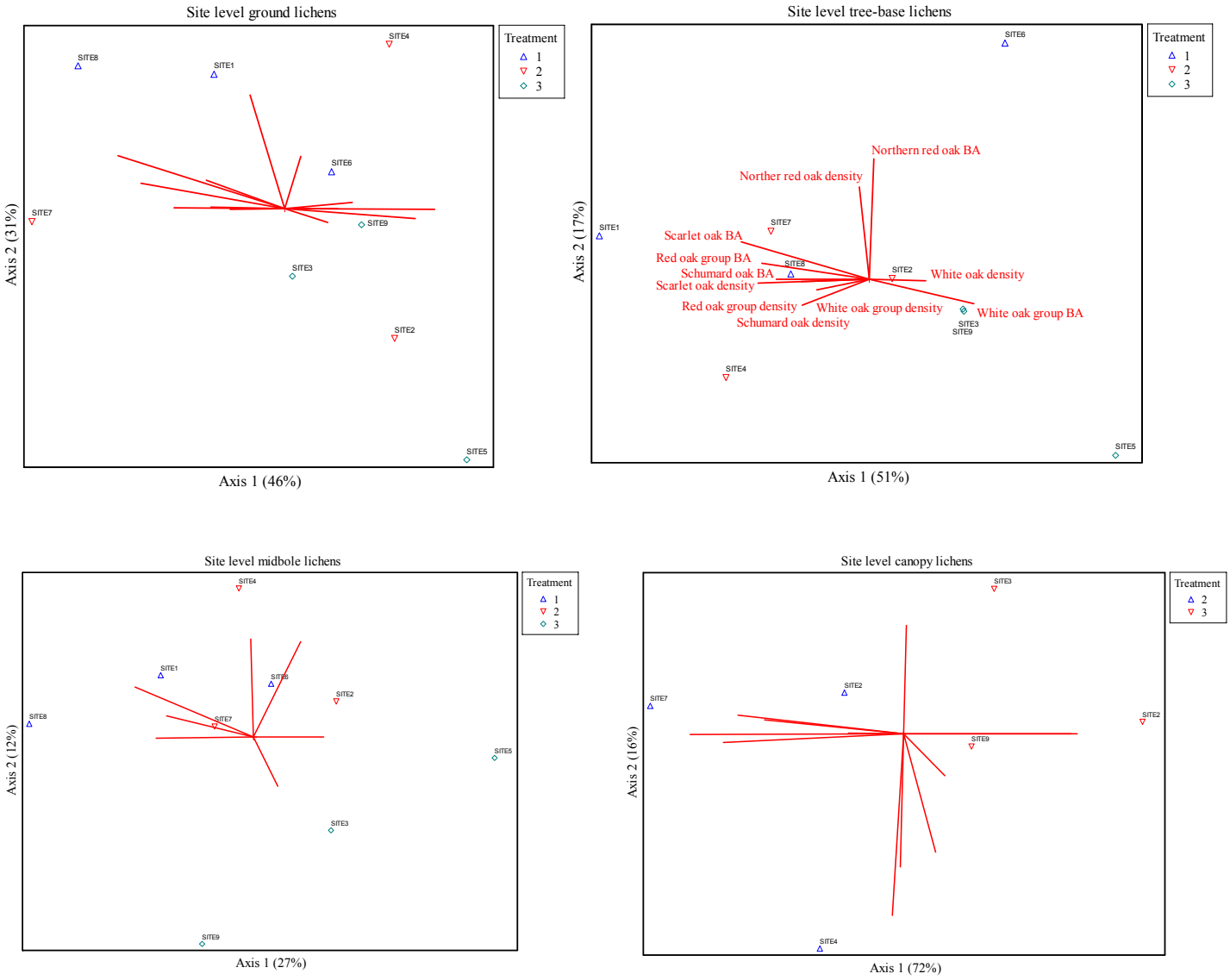


Figure 5. Ordination diagram showing the strong pattern of association of some typical and common species with the axes associated with various oak species for the ground, tree-base, midbole, and canopy habitats (Table 3). The length of the lines is proportional to the magnitude of the correlation of that variable with the ordination axes. All ordinations have been rotated such that white oak basal area corresponds to Axis 1 to facilitate comparison.

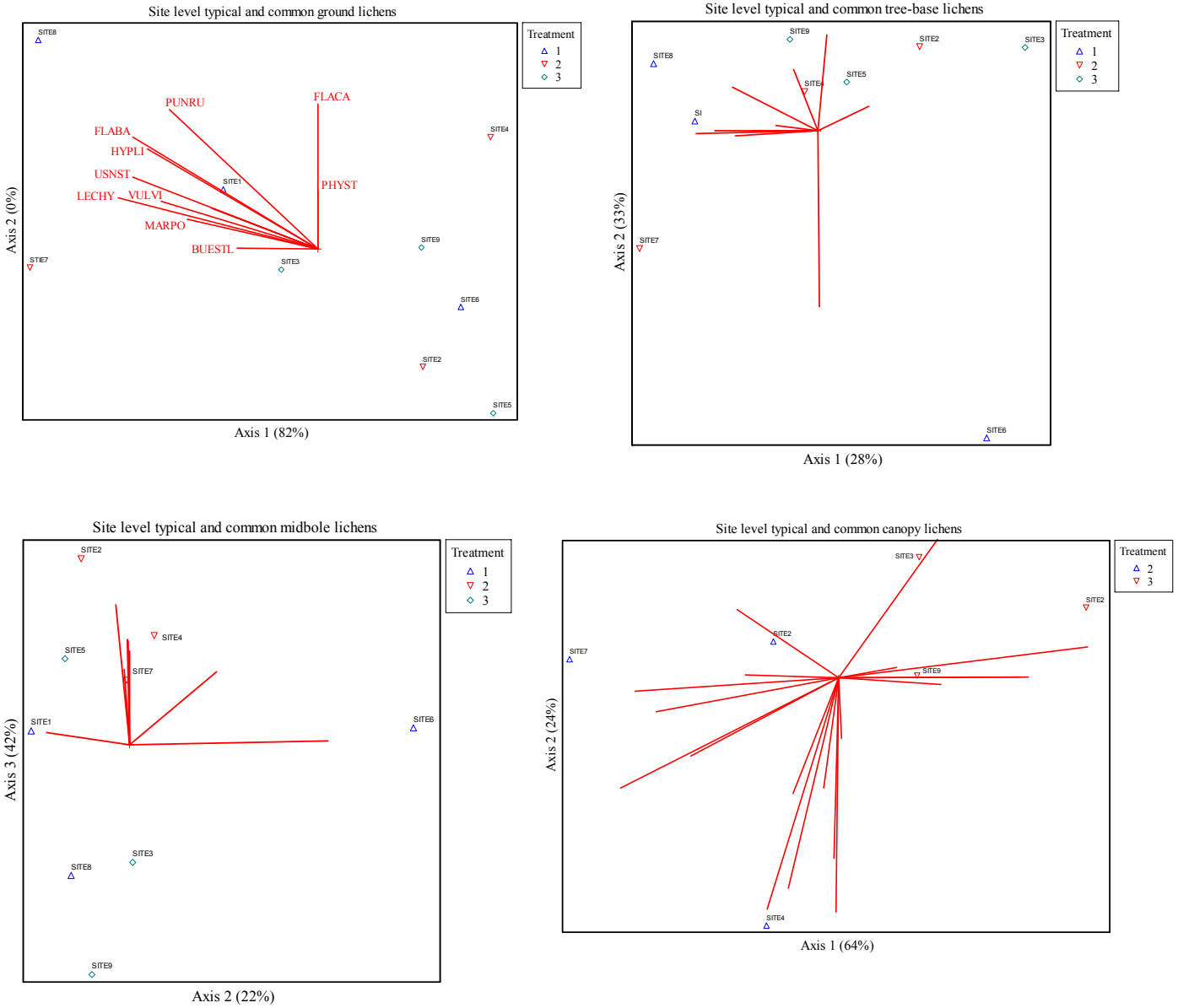


Figure 6. Ordination diagrams showing no pattern of lichen communities across sites for tree-base, midbole, canopy, and ground lichens. In all of the cases for tree samples, host tree species patterns transcended sites.

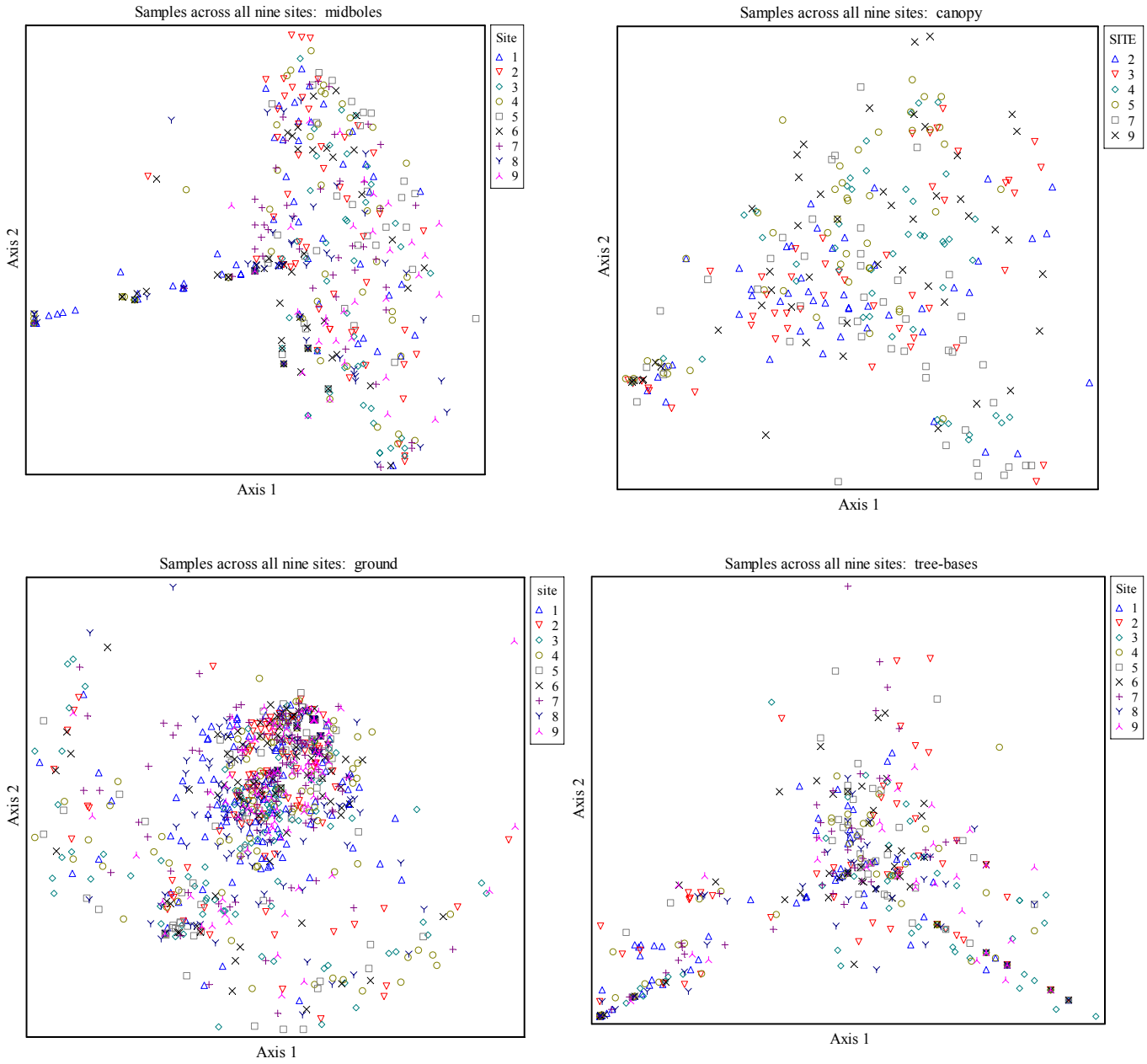


Figure 7. Ordination diagram showing the pattern of association of several site characteristics with the lichen communities. The length of the lines is proportional to the magnitude of the correlation of that variable with the ordination axes. Aspect Classes are 1=exposed, 2= neutral, and 3=protected.

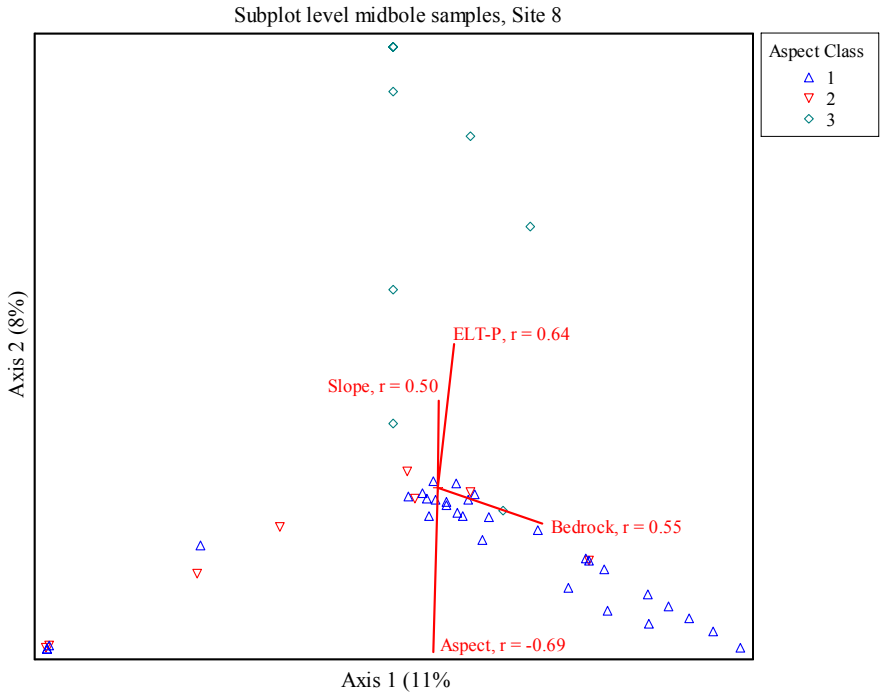


Figure 8. Species area curves for samples from the ground (top left), tree-bases (top right), midboles (bottom left) and canopy (bottom right), showing the continually climbing number of species as the total number of sites (nine for ground, tree-bases, and midboles and six for canopy) is reached.

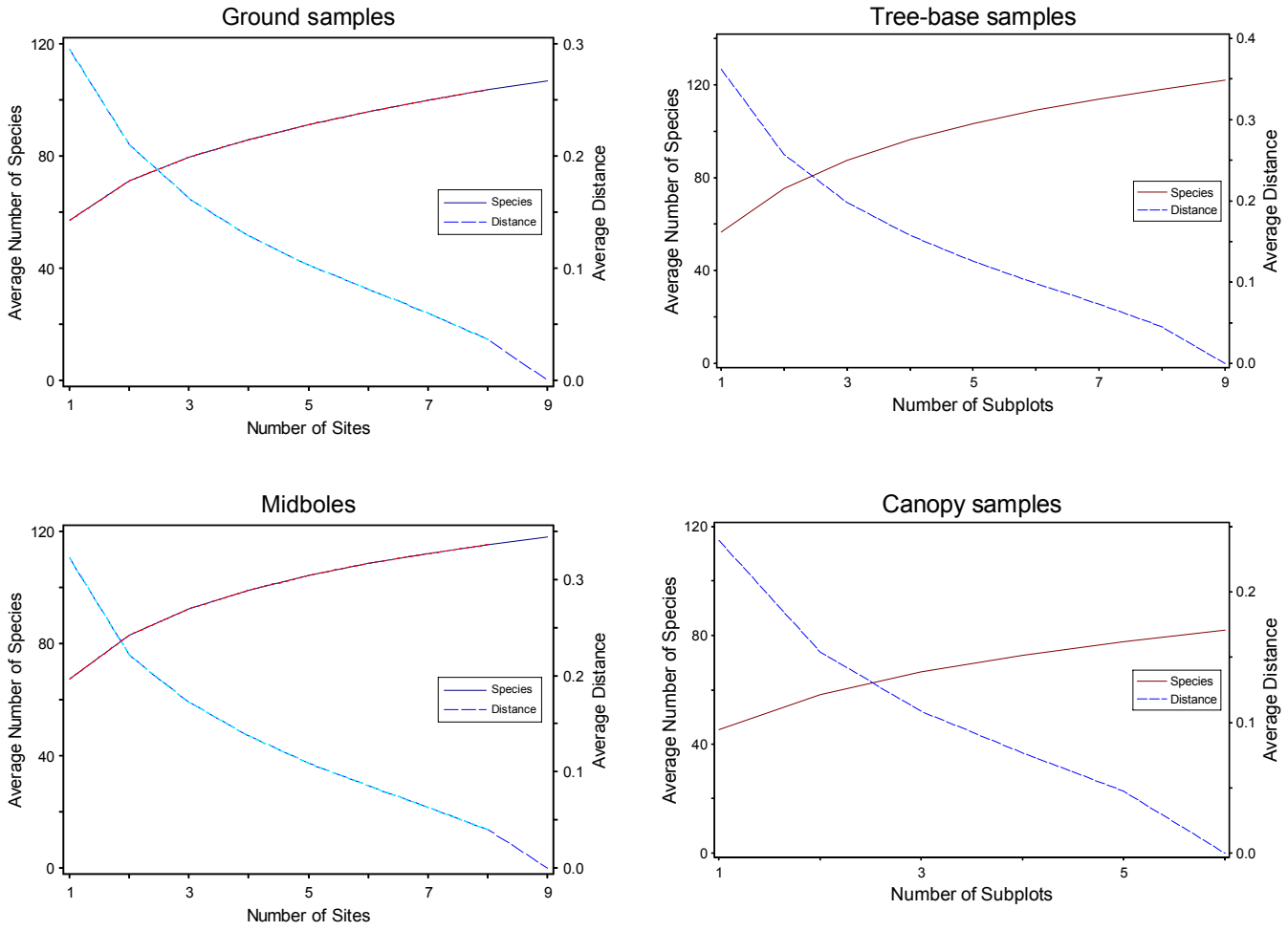
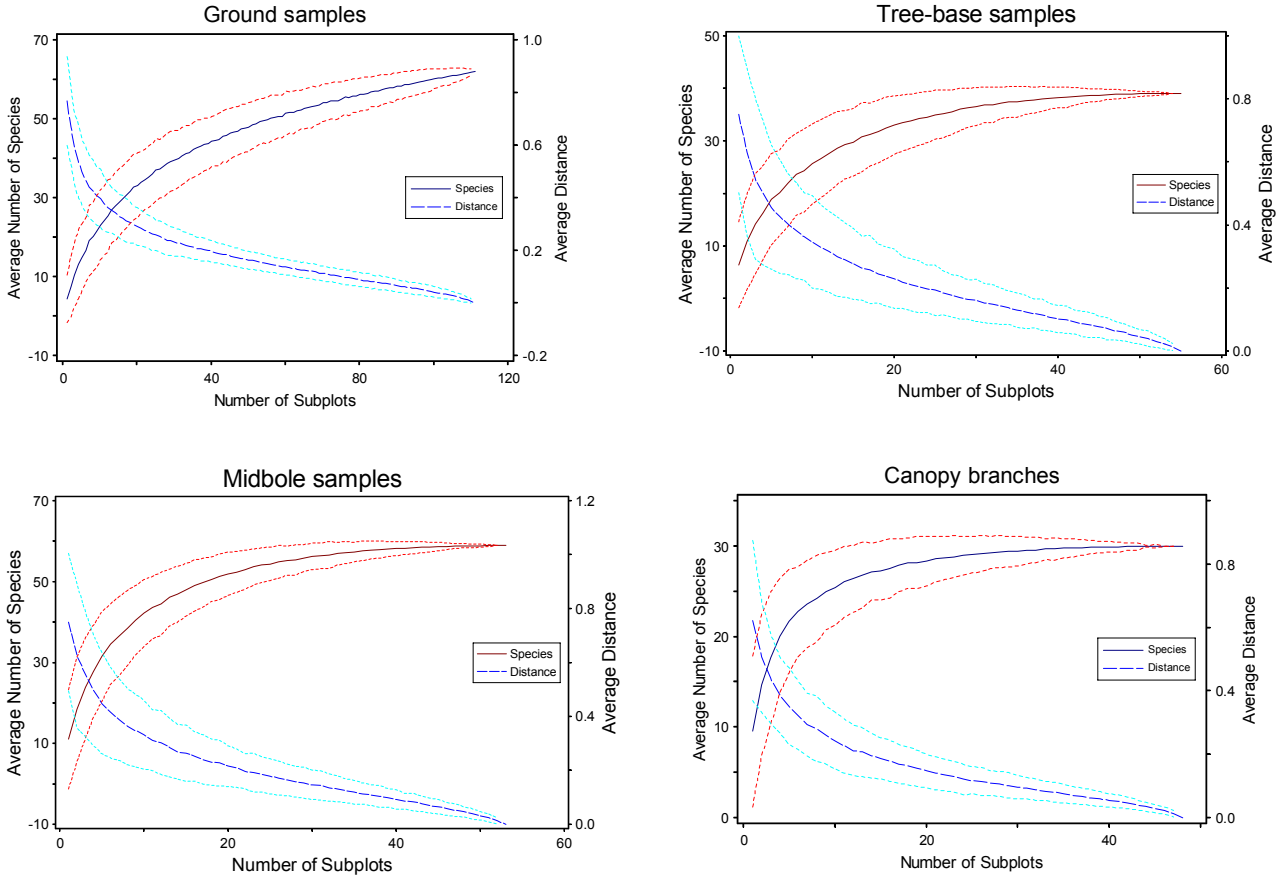


Figure 9. Species area curves for samples from the ground (top left), tree-bases (top right), midboles (bottom left), and canopy branches (bottom right), showing the number of species leveling off (canopy) and continuing to rise (ground) as the total number of subplots (111, 55, 54, and 48, respectively) in Site 2 is reached. The dotted lines are 95th percentile confidence intervals.



Appendix 1. Percent frequency of lichen species found in 9 MOFEP sites at the site-level and the subplot level by habitat. Superscripts identify members of the two identified species assemblages (t=typical, c=common), by habitat type (G=ground, B=tree-base, M=midbole, C=canopy). "N" indicates nitrogen fixing species, while "W" denotes species on the "watch list" for the state of Missouri (Ladd 1991).

			Ground		Tree-base		Midbole		Canopy	
	Species	Physiognomy	Site	Subplot	Site	Subplot	Site	Subplot	Site	Subplot
			n=9	n=999	n=9	n=435	n=9	n=434	n=6	n=283
ACAFU	Acarospora fuscata	crustose	44.4	0.7	0.0	0.0	0.0	0.0	0.0	0.0
AGOSP1	Agonimia sp. #1	crustose	0.0	0.0	55.6	2.3	11.1	0.2	0.0	0.0
AMADA	Amandinea dakotensis	crustose	0.0	0.0	0.0	0.0	0.0	0.0	16.7	0.3
AMAPO	Amandinea polyspora[Ct]	crustose	88.9	4.5	22.2	0.5	22.2	0.9	100.0	19.1
AMAPU	Amandinea punctata	crustose	0.0	0.0	44.4	3.9	44.4	1.8	0.0	0.0
ANAPA	Anaptychia palmulata	foliose	0.0	0.0	22.2	0.7	0.0	0.0	0.0	0.0
ANINY	Anisomeridium nyssaegenum	crustose	0.0	0.0	77.8	3.5	55.6	1.6	16.7	0.3
ARTspp	Arthonia sp.	crustose	22.2	0.4	0.0	0.0	11.1	0.2	0.0	0.0
ARTCA	Arthonia caesia[Gt Ct]	crustose	100.0	14.4	55.6	1.8	88.9	5.1	100.0	15.6
ARTDI	Arthonia dispersa	crustose	0.0	0.0	11.1	0.7	22.2	0.5	0.0	0.0
ARTPU	Arthonia punctiformis[Ct]	crustose	55.6	1.0	0.0	0.0	0.0	0.0	100.0	42.0
ARTPY	Arthonia pyrrhuliza	crustose	0.0	0.0	22.2	0.5	88.9	6.2	50.0	1.8
ARTRA	Arthonia radiata/pyrrhuliza	crustose	0.0	0.0	11.1	0.2	0.0	0.0	0.0	0.0
ARTSP	Arthothelium spectabile	crustose	11.1	0.7	0.0	0.0	0.0	0.0	16.7	0.3
ARTTA	Arthothelium taediosum[Bc Cc]	crustose	100.0	2.2	44.4	1.1	100.0	16.1	100.0	43.5
ASPspp	Aspicilia sp.	crustose	55.6	1.9	0.0	0.0	0.0	0.0	0.0	0.0
ASPCS	Aspicilia caesiocinerea	crustose	55.6	0.5	0.0	0.0	0.0	0.0	0.0	0.0
BACspp	Bacidia sp.	crustose	33.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0
BACCI	Bacidia circumspecta	crustose	0.0	0.0	11.1	0.2	0.0	0.0	0.0	0.0
BACDI	Bacidia diffracta	crustose	0.0	0.0	11.1	0.2	0.0	0.0	0.0	0.0
BACLA	Bacidia laurocerasi	crustose	0.0	0.0	0.0	0.0	11.1	0.2	0.0	0.0
BACPO	Bacidia polychroa	crustose	66.7	1.4	100.0	5.8	88.9	7.8	0.0	0.0
BACSC	Bacidia schweinetzii[Mt]	crustose	77.8	1.0	100.0	15.6	100.0	13.6	16.7	0.3
BACSU	Bacidia suffusa	crustose	11.1	0.1	22.2	0.5	44.4	1.6	16.7	0.3
BUEspp	Buellia sp.	crustose	44.4	1.0	0.0	0.0	0.0	0.0	0.0	0.0
BUESP	Buellia spuria	crustose	88.9	6.7	0.0	0.0	0.0	0.0	0.0	0.0
BUESTL	Buellia stillingiana[Gt Bt Ct]	crustose	100.0	15.9	77.8	4.1	100.0	21.9	100.0	49.5
CALspp	Caloplaca sp.	crustose	11.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
CALBR	Caloplaca brunneola	crustose	0.0	0.0	11.1	0.2	11.1	0.2	50.0	1.1
CALCA	Caloplaca camptidia	crustose	66.7	0.6	88.9	4.4	100.0	14.1	33.3	1.1
CALCE	Caloplaca cerina	crustose	66.7	1.3	33.3	0.7	77.8	4.6	16.7	0.7
CALFLB	Caloplaca flavorubescens	crustose	22.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
CALFLV	Caloplaca flavovirescens	crustose	0.0	0.0	0.0	0.0	0.0	0.0	16.7	0.3
CALPO	Caloplaca pollinii	crustose	33.3	0.4	0.0	0.0	55.6	2.3	0.0	0.0
CANCO	Candelaria concolor[Bt]	foliose	100.0	4.5	100.0	18.2	100.0	46.3	66.7	4.2
CANFI	Candelaria fibrosa	foliose	11.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
CANRE	Candelariella reflexa	crustose	11.1	0.1	0.0	0.0	22.2	0.5	83.3	6.0
CANXA	Candelariella xanthostigma	crustose	77.8	2.9	44.4	1.1	100.0	6.0	0.0	0.0
CNOspp	Canoparmelia sp.	foliose	55.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0
CANCA	Canoparmelia caroliniana	foliose	0.0	0.0	22.2	1.4	11.1	0.2	0.0	0.0
RIMSUT	Canoparmelia subtinctoria	foliose	33.3	0.6	100.0	6.2	88.9	7.6	0.0	0.0

CANTE	Canoparmelia texana[Cc]	foliose	22.2	0.4	44.4	2.8	44.4	3.2	100.0	10.3
CATNI	Catillaria nigroclavata	crustose	0.0	0.0	0.0	0.0	11.1	0.2	0.0	0.0
CHANA	Chaenothecopsis nana	crustose	0.0	0.0	44.4	3.0	44.4	4.8	0.0	0.0
CHARU	Chaenothecopsis rubescens	crustose	0.0	0.0	0.0	0.0	11.1	0.2	0.0	0.0
CLASU	Cladina subtenuis	fruticose	11.1	0.3	0.0	0.0	0.0	0.0	0.0	0.0
CDAPO	Cladonia apodocarpa	fruticose	0.0	0.0	11.1	0.2	0.0	0.0	0.0	0.0
CDCRI	Cladonia cristatella	fruticose	0.0	0.0	11.1	0.2	0.0	0.0	0.0	0.0
CDCYL	Cladonia cylindrica	fruticose	0.0	0.0	11.1	0.2	0.0	0.0	0.0	0.0
CDGRA	Cladonia grayi	fruticose	0.0	0.0	88.9	4.6	0.0	0.0	0.0	0.0
CDMABA	Cladonia macilenta bacillaris	fruticose	11.1	0.2	44.4	3.5	22.2	0.5	0.0	0.0
CDPAR	Cladonia parasitica	fruticose	0.0	0.0	11.1	0.2	0.0	0.0	0.0	0.0
CDPEZ	Cladonia peziziformis	fruticose	0.0	0.0	88.9	3.0	0.0	0.0	0.0	0.0
CDPOLS	Cladonia polycarpoides	fruticose	11.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
CDsqm	Cladonia sp. squamules[Bc]	fruticose	100.0	21.2	100.0	50.3	100.0	21.2	0.0	0.0
COCPA	Coccocarpia palmicola[N]	foliose	22.2	0.2	33.3	0.9	0.0	0.0	0.0	0.0
COLCON	Collema conglomeratum[N]	gelatinous	0.0	0.0	22.2	0.5	22.2	0.5	0.0	0.0
COLFUR	Collema furfuraceum[N]	gelatinous	0.0	0.0	100.0	11.0	88.9	5.5	0.0	0.0
DENIN	Dendriscocaulon intricatulum[N]	fruticose	0.0	0.0	11.1	0.5	11.1	0.2	0.0	0.0
DIMSP	Dimerella sp. #1	crustose	0.0	0.0	22.2	0.5	22.2	0.5	0.0	0.0
DIMPI	Dimerella pineti	crustose	0.0	0.0	0.0	0.0	11.1	0.2	0.0	0.0
ENDPU	Endocarpon pusillum	crustose	11.1	0.1	22.2	0.5	0.0	0.0	0.0	0.0
FLABA	Flavoparmelia baltimorensis[Gc]	foliose	88.9	10.7	22.2	0.5	0.0	0.0	0.0	0.0
FLACA	Flavoparmelia caperata[Gt Mc Bt Ct]	foliose	100.0	19.4	100.0	32.0	100.0	35.7	100.0	41.7
GRASC	Graphis scripta[Bt]	crustose	100.0	3.7	66.7	3.7	100.0	22.8	16.7	0.3
GYDSP1	Gyalideopsis sp. #1	crustose	0.0	0.0	0.0	0.0	0.0	0.0	16.7	0.3
HETGR	Heterodermia granulifera	foliose	11.1	0.1	22.2	0.7	22.2	0.5	16.7	0.3
HETHY	Heterodermia hypoleuca	foliose	0.0	0.0	11.1	0.2	33.3	0.7	16.7	0.3
HETOB	Heterodermia obscurata[Bt]	foliose	11.1	0.2	100.0	14.9	100.0	29.0	33.3	1.8
HETSP	Heterodermia speciosa[Mt]	foliose	88.9	1.0	100.0	32.0	100.0	14.1	16.7	0.3
HYPLI	Hypotrachyna livida[Gt Cc]	foliose	100.0	12.9	33.3	0.9	77.8	5.8	100.0	32.9
HYPSY	Hyperphyscia syncolla	foliose	0.0	0.0	0.0	0.0	0.0	0.0	16.7	0.3
JULFA	Julella fallaciosa	crustose	0.0	0.0	55.6	1.1	77.8	3.0	50.0	1.1
LECspp	Lecanora sp.	crustose	11.1	0.1	33.3	0.9	0.0	0.0	0.0	0.0
LECSP1	Lecanora sp. [usnic acid, zeorin]	crustose	0.0	0.0	0.0	0.0	11.1	0.2	0.0	0.0
LECCAPR	Lecanora caesiorubella prolife[Ct]	crustose	77.8	3.9	33.3	0.9	100.0	11.8	100.0	23.3
LECDI	Lecanora dispersa	crustose	11.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
LECHY	Lecanora hybocarpa[Gt Bt Ct]	crustose	100.0	23.2	88.9	7.1	100.0	33.4	100.0	51.6
LECIM	Lecanora imshaugii	crustose	0.0	0.0	0.0	0.0	22.2	0.7	0.0	0.0
LECMI	Lecanora minutella	crustose	0.0	0.0	0.0	0.0	22.2	1.1	0.0	0.0
LECST	Lecanora strobilina[Gt Bt Cc]	crustose	100.0	78.0	100.0	14.3	100.0	28.1	100.0	80.6
LECTH	Lecanora thysanophora	crustose	0.0	0.0	11.1	0.2	11.1	0.2	0.0	0.0
LECVA	Lecidea varians[Cc]	crustose	88.9	7.7	0.0	0.0	55.6	3.9	100.0	42.0
LEPLO	Lepraria lobificans[Mc]	crustose	55.6	1.7	100.0	28.5	100.0	9.0	0.0	0.0
LEPspp	Lepraria sp.	crustose	11.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
LEPSP1	Lepraria sp. #1[Mc Bc]	crustose	33.3	0.4	88.9	26.2	100.0	24.9	50.0	2.5
LEPAU	Leptogium austroamericanum[N]	gelatinous	0.0	0.0	77.8	2.1	22.2	0.5	0.0	0.0
LEPCY	Leptogium cyanescens[N]	gelatinous	0.0	0.0	88.9	9.4	55.6	3.0	0.0	0.0
LEPDA	Leptogium dactylinum[N]	gelatinous	0.0	0.0	44.4	1.6	0.0	0.0	0.0	0.0
LEPMI	Leptogium milligranum[N]	gelatinous	11.1	0.1	88.9	4.1	88.9	6.0	0.0	0.0
LOXPU	Loxospora pustulata[Mc Bc]	crustose	100.0	4.7	100.0	17.5	100.0	34.8	50.0	3.9

MARPO	Maronea polyphaea[Gt Ct]	crustose	100.0	12.7	44.4	2.1	88.9	9.9	100.0	39.2
MYCAL	Mycocalicium albonigrum	crustose	22.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
MYCSU	Mycocalicium subtile	crustose	0.0	0.0	0.0	0.0	11.1	0.2	0.0	0.0
MYCQU	Mycoglaena quercicola	crustose	0.0	0.0	0.0	0.0	0.0	0.0	83.3	6.4
MYCPY	Mycoporum pycnocarpoides	crustose	22.2	0.3	0.0	0.0	55.6	1.8	50.0	2.1
MYEAU	Myelochroa aurulenta[Gc Mt Bt]	foliose	100.0	11.7	100.0	47.4	100.0	41.2	100.0	4.2
MYEGA	Myelochroa galbina[Gt Cc]	foliose	100.0	10.4	33.3	1.1	88.9	6.9	100.0	47.3
NADSO	Nadvornikia sorediata	crustose	0.0	0.0	11.1	0.2	11.1	0.2	0.0	0.0
NECPA	Nectria parmeliae	crustose	0.0	0.0	11.1	0.2	0.0	0.0	0.0	0.0
OCHAF	Ochrolechia africana	crustose	33.3	0.3	0.0	0.0	44.4	2.1	50.0	1.1
OPEVA	Opegrapha varia	crustose	11.1	0.1	55.6	2.3	66.7	2.5	0.0	0.0
OPEVU	Opegrapha vulgata	crustose	0.0	0.0	0.0	0.0	22.2	0.5	0.0	0.0
PANLU	Pannaria lurida[N]	foliose	0.0	0.0	11.1	0.2	11.1	0.2	0.0	0.0
PARMIN	Parmelinopsis minarum	foliose	33.3	0.6	77.8	4.6	55.6	2.5	16.7	0.3
PARAU	Parmotrema austrosinense	foliose	22.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
PARnis	Parmotrema [hypt/perf][Cc]	foliose	0.0	0.0	11.1	0.2	11.1	0.2	100.0	15.9
PAREU	Parmotrema eurysacum/despectum	foliose	100.0	6.0	44.4	1.1	88.9	4.4	16.7	0.3
PARGA	Parmotrema gardneri	foliose	0.0	0.0	11.1	0.2	0.0	0.0	16.7	0.3
PARHYPT	Parmotrema hypotropum[Mc Cc]	foliose	100.0	6.3	100.0	14.0	100.0	13.4	83.3	11.3
PARMIC	Parmotrema michauxianum	foliose	22.2	0.2	11.1	0.2	11.1	0.2	16.7	0.3
PARPE	Parmotrema perforatum[Cc]	foliose	55.6	0.7	0.0	0.0	0.0	0.0	100.0	9.9
PELspp	Peltigera sp.[N]	foliose	11.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
PERspp	Pertusaria sp.	crustose	88.9	3.2	0.0	0.0	0.0	0.0	0.0	0.0
PERAM	Pertusaria amara	crustose	33.3	0.4	44.4	2.5	100.0	10.1	33.3	1.1
PERHY	Pertusaria hypothamnolica	crustose	0.0	0.0	11.1	0.2	55.6	1.6	33.3	1.4
PERMA	Pertusaria macounii	crustose	0.0	0.0	0.0	0.0	22.2	0.5	0.0	0.0
PERNE	Pertusaria neoscotica	crustose	11.1	0.1	11.1	0.2	0.0	0.0	0.0	0.0
PEROS	Pertusaria ostiolata	crustose	0.0	0.0	100.0	5.1	88.9	5.8	16.7	0.3
PERPA	Pertusaria paratuberculifera[Mt Bc]	crustose	77.8	0.9	100.0	28.7	100.0	22.1	66.7	4.9
PERPR	Pertusaria propinqua	crustose	0.0	0.0	11.1	0.2	66.7	3.0	66.7	1.8
PERPU	Pertusaria pustulata[Ct]	crustose	88.9	3.3	66.7	2.3	100.0	13.4	100.0	28.6
PERSU	Pertusaria subpertusa	crustose	0.0	0.0	11.1	0.2	77.8	4.8	50.0	2.5
PERTET	Pertusaria tetrathalmia	crustose	11.1	0.1	44.4	1.1	66.7	2.3	16.7	0.3
PERTEX	Pertusaria texana	crustose	22.2	0.2	55.6	1.4	100.0	11.8	66.7	4.6
PERTR	Pertusaria trachythallina	crustose	0.0	0.0	11.1	0.2	44.4	1.1	100.0	7.1
PERVA	Pertusaria valliculata	crustose	0.0	0.0	33.3	0.7	44.4	1.4	0.0	0.0
PERVE	Pertusaria velata	crustose	11.1	0.1	66.7	2.1	88.9	6.0	33.3	1.1
PHAPO	Phaeocalicium polyporaeum	crustose	11.1	0.1	22.2	0.5	22.2	0.5	0.0	0.0
PHAAD	Phaeophyscia adiastola	foliose	11.1	0.1	11.1	0.9	0.0	0.0	0.0	0.0
PHACE	Phaeophyscia cernohorskyi	foliose	0.0	0.0	0.0	0.0	33.3	0.9	0.0	0.0
PHACI	Phaeophyscia ciliata	foliose	0.0	0.0	0.0	0.0	11.1	0.5	0.0	0.0
PHAHIRS	Phaeophyscia hirsuta	foliose	11.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
PHAPU	Phaeophyscia pusilloides[Mt Bt]	foliose	100.0	4.8	100.0	26.7	100.0	31.3	50.0	1.4
PHARU	Phaeophyscia rubropulchra[Mt Bt]	foliose	100.0	3.0	100.0	35.4	100.0	18.9	33.3	1.1
PHASQ	Phaeophyscia squarrosa	foliose	11.1	0.1	33.3	0.9	0.0	0.0	0.0	0.0
PHLAR	Phlyctis argena	crustose	22.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
PHYCO	Phyllopsora corallina	crustose	0.0	0.0	22.2	0.9	0.0	0.0	0.0	0.0
PHYspp	Physcia sp.	foliose	55.6	2.6	0.0	0.0	0.0	0.0	0.0	0.0
PHYAM	Physcia americana[Mc Bt]	foliose	100.0	5.9	100.0	36.8	100.0	57.4	16.7	0.7
PHYMI	Physcia millegrana	foliose	88.9	4.4	55.6	2.1	88.9	12.2	66.7	5.3

PHYPU	Physcia pumilior	foliose	11.1	0.2	22.2	0.5	44.4	1.8	83.3	2.8
PHYST	Physcia stellaris[Gt Ct]	foliose	100.0	18.5	55.6	1.1	100.0	4.6	100.0	25.1
PHYSU	Physcia subtilis	foliose	77.8	2.9	0.0	0.0	0.0	0.0	0.0	0.0
PHYCH	Physciella chloantha	foliose	0.0	0.0	0.0	0.0	11.1	0.2	16.7	0.7
PHYME	Physciella melanchra	foliose	0.0	0.0	11.1	0.7	22.2	0.5	0.0	0.0
PHYDE	Physconia detersa	foliose	0.0	0.0	55.6	1.8	66.7	2.5	0.0	0.0
PLATU	Placidium tuckermanii	crustose	0.0	0.0	44.4	1.8	55.6	1.8	0.0	0.0
PUNMI	Punctelia missouriensis	foliose	0.0	0.0	11.1	0.2	0.0	0.0	0.0	0.0
PUNRU	Punctelia rudecta[Gt Mt Bt Ct]	foliose	100.0	35.9	100.0	45.8	100.0	52.8	100.0	38.2
PUNSU	Punctelia subrudecta	foliose	0.0	0.0	11.1	0.2	0.0	0.0	33.3	0.7
PYRCA	Pyrenula caryae	crustose	0.0	0.0	0.0	0.0	0.0	0.0	33.3	1.8
PYRPS	Pyrenula pseudobufonia[Bc]	crustose	55.6	1.0	33.3	0.9	100.0	17.7	33.3	1.1
PYXSO	Pyxine sorediata	foliose	66.7	1.5	88.9	11.7	100.0	19.8	66.7	2.5
PYXSU	Pyxine subcinerea[Bc Cc]	foliose	77.8	2.2	88.9	7.1	100.0	23.3	100.0	29.7
RAMAM	Ramalina americana	fruticose	22.2	0.2	0.0	0.0	44.4	2.1	0.0	0.0
RAMAML	Ramalina culbersoniorum	fruticose	0.0	0.0	0.0	0.0	0.0	0.0	33.3	1.1
RIMCE	Rimelia cetrata	foliose	11.1	0.1	0.0	0.0	22.2	0.9	33.3	0.7
RIMRE	Rimelia reticulata[Bc]	foliose	100.0	2.7	88.9	10.8	100.0	14.8	66.7	4.6
RIMSU	Rimelia subisidiosa	foliose	66.7	1.0	11.1	0.2	11.1	0.2	16.7	0.3
RINspp	Rinodina sp.	crustose	11.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
RINAP	Rinodina applanata	crustose	0.0	0.0	11.1	0.2	11.1	0.5	33.3	0.7
RINSU	Rinodina subminuta	crustose	0.0	0.0	44.4	0.9	22.2	0.9	16.7	0.7
RINTE	Rinodina tephraspis	crustose	11.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
ROBPU	Robergea pupula	crustose	0.0	0.0	11.1	0.2	33.3	0.7	0.0	0.0
OPEBR	Schismatomma glaucescens	crustose	0.0	0.0	11.1	0.2	33.3	0.9	0.0	0.0
STRJA	Strigula jamesii	crustose	0.0	0.0	33.3	1.1	0.0	0.0	0.0	0.0
THEFL	Thelopsis flaveola	crustose	0.0	0.0	22.2	0.5	55.6	1.4	0.0	0.0
TRAFL	Trapeliopsis flexuosa	crustose	88.9	2.4	22.2	0.5	11.1	0.5	0.0	0.0
TUCCI	Tuckermannopsis ciliaris[W]	foliose	0.0	0.0	11.1	0.2	0.0	0.0	0.0	0.0
TUCFE	Tuckermannopsis fendleri	foliose	88.9	4.7	0.0	0.0	0.0	0.0	16.7	0.3
unkcr1	unknown crust A[Gc Cc]	crustose	100.0	13.4	77.8	6.9	100.0	6.4	66.7	13.1
unkcr2	unknown crust B	crustose	0.0	0.0	22.2	0.5	33.3	1.1	16.7	0.3
unkfo	unknown foliose	foliose	11.1	0.1	22.2	0.5	0.0	0.0	0.0	0.0
unkge	unknown gelatinous	gelatinous	11.1	0.4	0.0	0.0	0.0	0.0	0.0	0.0
unkpy	unknown pyrenocarp	crustose	77.8	2.3	33.3	0.7	11.1	0.5	0.0	0.0
USNMU	Usnea mutabilis	fruticose	0.0	0.0	11.1	0.5	11.1	0.5	0.0	0.0
USNST	Usnea strigosa[Gt Cc]	fruticose	100.0	21.4	33.3	2.1	88.9	5.8	100.0	53.0
VULVI	Vulpicidia viridis[Gt Cc]	foliose	100.0	17.9	0.0	0.0	33.3	0.9	100.0	34.6
XANSU	Xanthoparmelia subramigera	foliose	22.2	0.3	0.0	0.0	0.0	0.0	0.0	0.0
XANFU	Xanthoria fulva	foliose	0.0	0.0	0.0	0.0	11.1	0.2	0.0	0.0